BUILDING CONSTRUCTION

FOR

BEGINNERS

BY

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WITH SIX HUNDRED AND EIGHTY-TWO ILLUSTRATIONS

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PREFACE

THE method upon which this book is arranged agrees closely with a scheme of work which I have adopted for several years in teaching the principles of Building Construction to large evening classes.

With the object of making the various details of construction as clear and obvious as possible, an unusually large number of figures is introduced. It will be noticed that very extensive use is made of Isometric Projection, a method of representation the value of which does not appear to be fully recognised. The help it affords to the young student can only be appreciated by those teachers who know how difficult it is for the untrained mind to build up a satisfactory mental picture of a solid object from elevations, plans, and sections.

I have purposely abstained from crowding the illustrations with dimension lines and numbers—a custom which discourages and too often bewilders the beginner, as it renders him "unable to see the wood for the trees."

Chapter fourteen is devoted to an account—necessarily brief—of the principal materials used in the construction

of buildings. There seems to be no reason why this important subject should be relegated, as it generally is, to the more advanced text-books.

At the ends of the chapters are brief summaries of the most important points in them, and also carefully graduated series of original exercises. Each of these series is supplemented by questions taken from past examination papers of the Board of Education, the Midland Counties Union of Educational Institutes, and the Union of Lancashire and Cheshire Institutes.

I am glad to avail myself of this opportunity of expressing my grateful acknowledgments to Sir Richard Gregory and Mr. A. T. Simmons, B.Sc., for their continuous and kindly help in matters of arrangement and expression during the work of preparing this little volume.

J. W. RILEY.

ROCHDALE.

CONTENTS

CHAPTER I

INTRODUCTION

Objects of Study.—This book is intended to give an elementary outline of the principles underlying the construction of buildings, of the materials employed, and of the manner in which these materials are arranged among themselves to secure the best results. It is important that those engaged in the various branches of the building trade should know, not only the principles of their own particular work in a building, but also the relations existing between their work and the rest of the structure. There is no surer means of acquiring such intelligent knowledge than by making drawings to scale of the different parts of buildings. Since all buildings are erected according to drawings embodying the ideas of the designer, it is evident that a knowledge of such drawings is not only advisable but absolutely necessary to all engaged in the construction of the buildings. The practice of drawing also compels the student to give close attention to details which would otherwise escape his notice.

Drawing Instruments.—The student should provide himself with a drawing-board, Tee and set squares, dividers, compasses, drawing-pen, drawing-pins, pencils, india-rubber, scales, Indian ink, colours, and brushes.

For ordinary class-work the drawing-board (preferably of yellow pine) may conveniently be twenty-three inches (23″) long and sixteen inches (16″) wide. It will then be suitable for use with half an imperial sheet of drawing-paper. The Tee square, which may have either a tapering or parallel blade, should be slightly longer than the board. To allow the set squares to

slide over the stock of the Tee square, it is better to have the blade screwed on to the stock rather than let in flush. Two set squares, *a* and *b*, Fig. 1, are required. These may be of

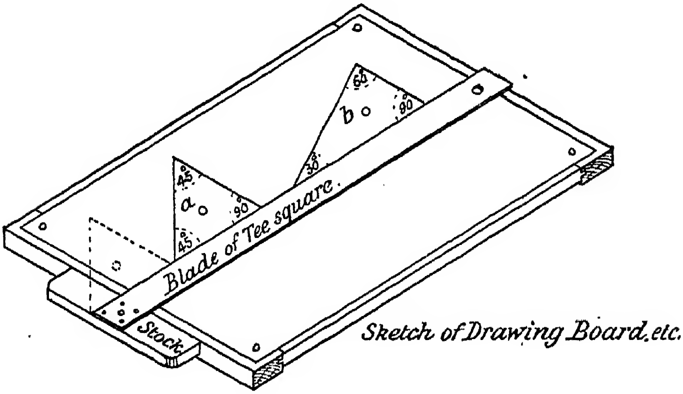


Fig. 1

wood, but are better of vulcanite or celluloid. Inexperienced students would do well to seek advice before purchasing such instruments as dividers, compasses, inking-pen, etc., as many cheap but almost worthless sets are put upon the market. HB pencils are used for taking notes, but harder pencils are necessary for drawing. H or HH are the most suitable. Cheap pencils of poor quality should be carefully avoided. The method of sharpening pencils deserves attention. Figs. 2 and 3 show a pencil sharpened with a chisel-point. A point formed in this manner will last longer than the rounded point shown in Fig. 4.

Chisel point.

Fig. 2. Fig. 3. Fig. 4.

Scales.—As very few details in building construction can be drawn of full size, some definite scale must be adopted.

The scale employed varies according to the work. Thus a whole building may be represented to a scale of one-eighth of an inch ($\frac{1}{8}''$) to the foot; it would, however, be impossible to show constructional details on such a small scale. Graduated rules of boxwood or paper may be obtained, on which are marked scales of $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 3, etc., inches to the foot. These scales are sufficient for ordinary work, but it is occasionally necessary to use other scales, and the student must know how to work these out for himself.

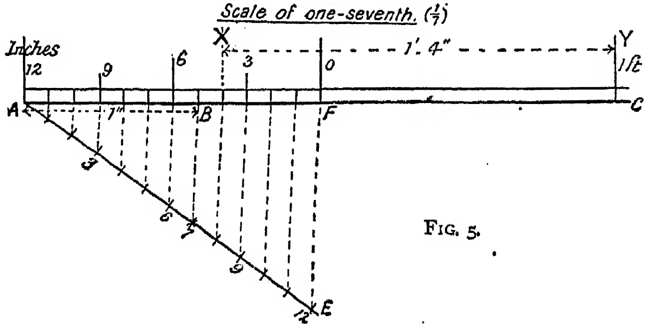


FIG. 5.

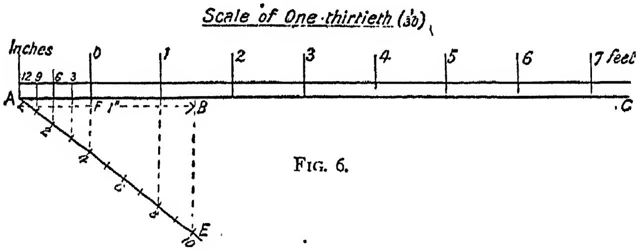


FIG. 6.

Example (1): *To construct a scale of one-seventh* ($\frac{1}{7}$) *the full size, to read to feet and inches.*—Draw a straight line AC (Fig. 5), and mark off AB one inch (1″) long. From A draw AE at any angle (preferably about 30°). On AE mark off any twelve (12) equal divisions, and number them. Join the *seventh* point to B, and through each of the other points on AE draw lines parallel to $B7$, and cutting AC. The length AB (1″) is thus divided into seven equal parts, each measuring one-seventh of an inch ($\frac{1}{7}''$). As the scale is one-seventh ($\frac{1}{7}$) full size, each division represents one inch, and the distance AF (twelve divisions) represents one foot. Mark the point

F zero, and number the scale as shown in Fig. 5. Then XY, *e.g.*, represents a distance of one foot four inches (1′ 4″).

Example (2): *To construct a scale of one-thirtieth* ($\frac{1}{30}$) *full size, so that one inch represents two feet six inches* (2′ 6″). On AC (Fig. 6) make AB equal to one inch, and on AE mark off ten (10) equal parts. Join the tenth point to B, and through the other points on AE draw lines parallel to B10, and cutting AB as shown. Then each of the smaller divisions on AB is one-tenth of an inch ($\frac{1}{10}$″) long, and therefore represents three inches (3″). Mark the *fourth* division from A zero, and number as shown in Fig. 6. AF represents one foot (1′), and AB two feet six inches (30″).

Inking-in and Colouring.—It is very advisable that students should, from the beginning, ink-in and colour all the drawings they make. While the most trustworthy Indian ink is that obtained by rubbing down the stick or cake in water on a china or porcelain saucer, liquid Indian ink of good quality is now easily obtainable. By its use the trouble of preparation is avoided. Care should be taken to always keep the inking-pen clean. Curves ought always to be inked-in before straight lines.

It is customary in colouring drawings to use definite colours for each of the various materials used in the work of construction. The following colours will be found sufficient for elementary work:—

Brickwork: Crimson lake.
Stonework: Sepia.
Earth (in section): Sepia.
Concrete: Sepia, speckled with Indian ink.
Woodwork (in the rough): Raw Sienna.
Woodwork (wrought): Burnt Sienna.
Lead: Deep Prussian blue or indigo.
Wrought iron: Prussian blue.
Slates: Prussian blue or neutral tint.
Plaster: Light tint of Prussian blue.
Glass: Light tint of Prussian blue or of indigo.
Cast iron: Payne's grey or sepia mixed with Prussian blue.

For surfaces in section the same colours may be used, but of a deeper tint. The best brushes for colouring are made of

sable, but camel-hair brushes may be used. Some practice is required before washes of colour can be laid on satisfactorily, and a few hints will be of use to beginners. Colour of the necessary tint should be mixed in a porcelain dish in sufficient quantity to cover the whole surface of the particular material. The lighter tints should be laid on first, and should be allowed to become quite dry before adjoining surfaces are coloured. More satisfactory work can be done with a large brush than with a small one. The wash should be commenced at the top left-hand corner, the board and paper being slightly inclined. Care should be taken not to mix the colour of too deep a tint, although it is not advisable to go over the same surface twice. In no circumstances should the coloured surface be interfered with before it is quite dry.

Elevations, Plans, and Sections.—It is necessary, in preparing drawings, to clearly show the dimensions of all the various parts. As it is not easy to do this in one drawing, it is customary to draw out different views. Thus the construction of a house cannot be properly represented without—

(1) A view of the front (**front elevation**).

(2) A view of the end (**end or side elevation**).

(3) A view from above (**plan**).

(4) Views such as would be obtained if certain parts were cut away (**sections**).

Fig. 7 is the *front elevation* of a small dwelling-house; and therefore shows the height and width of the building, with the positions and sizes of front window-openings and doorway. The distance from front to back, and the internal arrangements, cannot of course be seen from this drawing. The *end elevation* (Fig. 8) shows the dimensions of the end, and also indicates the slope of the roof. Figs. 10 and 11 are **horizontal sections** (or, as they are generally, though somewhat inaccurately, called, *plans*) of the same building taken above the ground floor and the first floor respectively. Such horizontal sections show the thickness of the walls, the size (except their height) and shape of the rooms, and the positions of doorways, fireplaces, staircase, etc. A true plan would of course show only the roof. As no one of these views shows either the height of the rooms, the depth of the floors, or the depth and arrangement of the foundations of the walls, one or more

vertical sections are necessary (Fig. 9). Whenever possible, the different views should be directly projected one from the other.

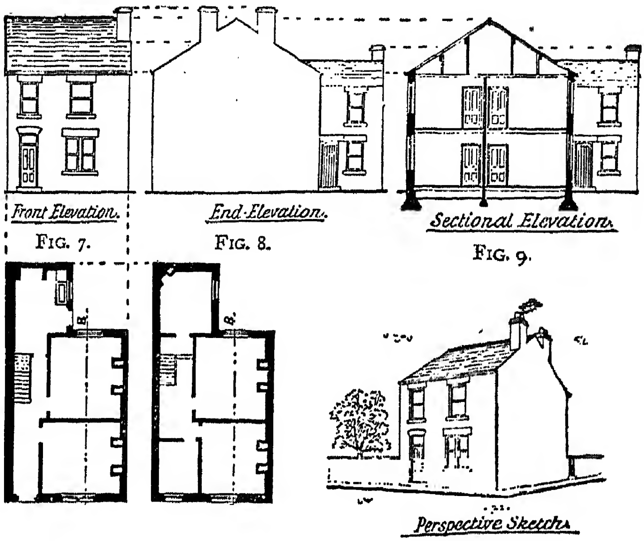


FIG. 7. FIG. 8. FIG. 9.

FIG. 10. FIG. 11. FIG. 12.

Different Views of a House.

Dimensions.—The conventional signs ′ and ″ are used to indicate feet and inches respectively. Arrow-headed dotted lines are used to show the lengths to which the dimensions refer.

Isometric Projection.—It is possible to show in one and the same drawing the length, breadth, and thickness of a solid drawn to scale. In general, therefore, such a drawing combines the essential features of front elevation, end elevation, and plan. This method is called *isometric projection.* Fig. 13 is an isometric sketch of an ordinary brick, with the dimensions marked thereon. The vertical edges are indicated by vertical straight lines, the other edges being represented by lines drawn at an angle of 30 degrees to the horizontal. This is the simplest case of isometric projection. It should be noted that the sketch is composed of three sets of parallel straight lines. That an isometric sketch is not, strictly speak-

ing, a true representation of an object as it appears to the eye, may be seen by a comparison of Fig. 13 with Fig. 14, which is a perspective drawing of the same brick. The isometric

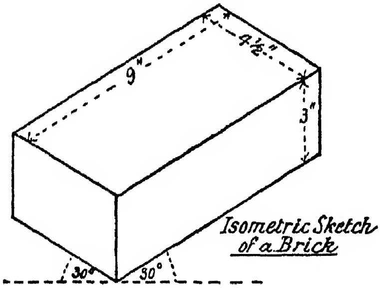


FIG. 13.

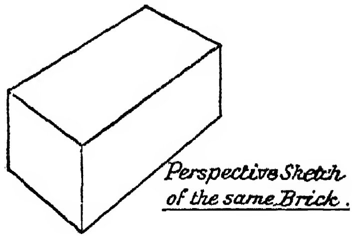


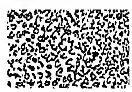
FIG. 14.

sketch has, however, the advantage that measurements may be taken directly from it, and that lines which are parallel in the object are also parallel in the drawing.

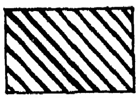
Conventional Sectioning. — Although students are

Brick
FIG. 15.

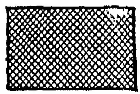
FIG. 16.



Concrete
FIG. 17.

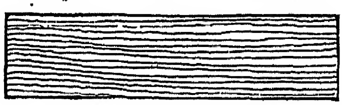


Wrought Iron.
FIG. 19.



Lead.
FIG. 20.

Cross Section Wood.
FIG. 21.



Longitudinal Section Wood.
FIG. 22.

Methods of Sectioning.

strongly recommended to colour their drawings whenever possible, it is not always convenient to do so. Under such conditions the parts of the drawing which are in section are indicated by section-lines, arranged differently for different

materials. Figs. 15 to 22 show the methods of sectioning adopted in this book.

Questions

1. A rectangular block of wood is 12″ long, 9″ wide, and 4″ thick. Draw the front and end elevations, plan, and an isometric sketch to a scale of $\frac{1}{8}$ full size.

Fig. 23.

2. Fig. 23 is the front elevation of three ordinary bricks, each 9″ × 4½″ × 3″. Draw the plan, end elevation, and isometric view of these to a scale of 1″ to the foot.

3. Fig. 24 is the plan of three bricks, one lying on the top of the other two. Draw the front and end elevations and an isometric sketch of the same to a scale of 1½″ to one foot.

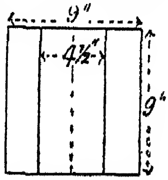


Fig. 24.

4. Draw front and end elevations, plan, and vertical section through *AB* of the ten bricks arranged as shown in isometric projection in Fig. 25. Scale, ¾″ to the foot.

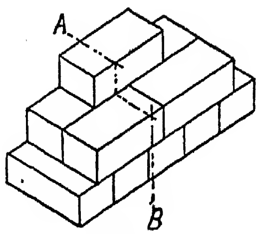


Fig. 25.

CHAPTER II

BRICKWORK

Uses of Stone and Bricks in a Building.—The materials used for the walls of buildings vary according to locality, climatic conditions, style of architecture, and the purposes for which the building is intended. Thus, in a district where **stone** is easily obtainable, this material is naturally chiefly used; while in places where clay is abundant, this is moulded into rectangular blocks of uniform size, which are dried and burnt, and thus formed into **bricks**, which, as is well known, largely take the place of stone for building purposes.

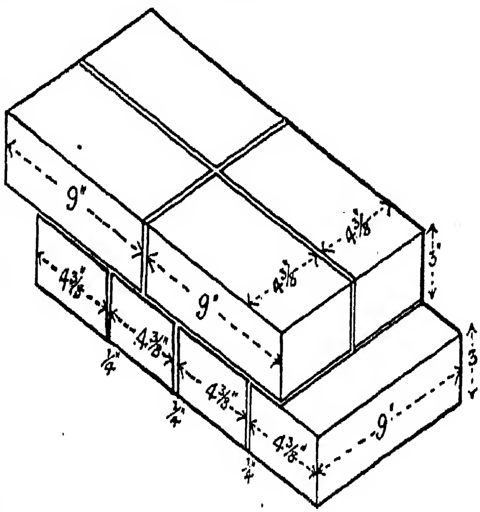


FIG. 26.—Showing thickness of mortar-joints.

The advantage of using bricks, in preference to stone, is that they are of uniform size, and hence lend themselves to regular arrangement, and to a system of overlapping whereby the various layers or courses are held together, and no continuous vertical joints occur. The size of bricks varies in different districts, but we may take the average size as being nine inches (9″) long, four and a half inches ($4\frac{1}{2}$″) wide, and three inches (3″) thick. In practice, however, the length should exceed twice the width by the thickness of a mortar-joint, in order that

the total width of two bricks and the mortar-joint between them may be equal to the length of one brick, as shown in Fig. 26.

Joints.—The thickness of the mortar-joints varies according to the quality of the bricks. Those used for superior work, and which have all their surfaces and edges (or, as they are generally called, **arrises**) straight and true, only require a joint about $\frac{1}{8}''$ thick, while common brickwork often requires joints as much as $\frac{3}{8}''$ thick.

We cannot do better than at once learn some of the technical terms in general use.

Stretchers are the bricks which are placed with their

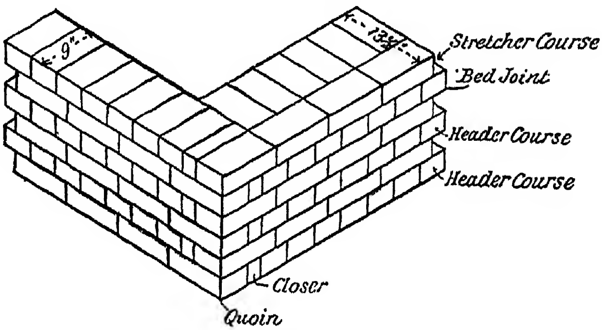


FIG. 27.—English Bond.

lengths in the direction of the length of the wall; they form, when so arranged, a *stretcher course* (Fig. 27).

Headers are placed with their length across the wall, showing $4\frac{1}{2}''$ on the face (Fig. 27), and together form a *header course.*

Bed joints are the mortar-joints between each course of bricks and the next. The courses are generally three inches (3") thick, as the bricks are laid flat, that is, on their largest rectangular faces. In arches, the bed-joints are the joints at right angles to the pressure of the arch (Fig. 77).

Quoins are the outside corners of a wall (Fig. 27).

The **Closer** is the name of the piece of brick inserted next the quoin-header in each alternate course, in order that the joints in the course shall not be in the same vertical line as those of the two adjacent courses. The closer may be a quarter-brick (Fig. 28), a half-brick cut longitudinally (Fig. 29) and named a **queen closer**, or a **king closer** (Fig. 30). The

last named is chiefly used to get a satisfactory arrangement of joints where a window-opening or doorway occurs.

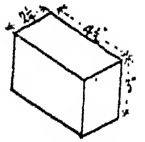


Fig. 28.—Quarter-brick Closer.

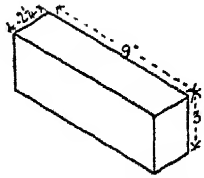


Fig. 29.—Queen Closer.

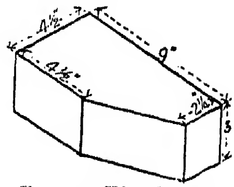


Fig. 30.—King Closer.

A closer is necessary in all walls more than one half-brick thick, for without it—the width of the brick being equal to about half the length—continuous vertical joints would occur at every stretcher length.

Precautions to be observed in Brickwork.—When bricks are received from the brickyard they are liable to be warm and covered with dust; all bricks should therefore in dry weather be wetted before being used, in order to wash off any dust and prevent too rapid absorption of the moisture of the mortar. Whenever new brickwork is joined to old, the old work should be swept clean and thoroughly wetted to ensure proper adhesion.

In the erection of buildings, all the walls should rise at about the same rate, no part being carried more than three feet above the rest, or unequal settlement may take place, with the result that the wall soon shows signs of fracture. If the walls cannot conveniently be carried up simultaneously, the portion first built should be **stepped back**, as at *A* in Fig. 31, rather than **toothed**, as shown at *B* in Fig. 31.

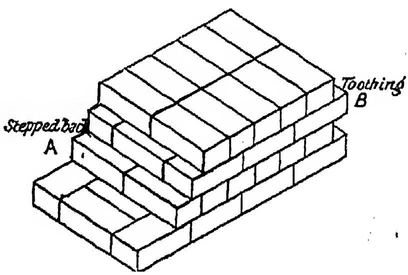


Fig. 31.—Stepping back and Toothing.

Reasons for Bonding.—The mortar-joints are the weakest parts of a wall. If the vertical joints were in continuous lines, the wall would tend to give way along these lines. To avoid this, "bonding" is resorted to.

"Bond": the Meaning of the Term.—Bond is the arrangement of the bricks to overlap each other in such a

manner that no continuous vertical joints occur, either on the face or in the inside of the wall.

Kinds of Bonds.—In **stretcher bond** all the bricks are placed with their lengths in the direction of the length of the wall (Fig. 32). This bond is only applicable to walls one half-brick ($4\frac{1}{2}''$) thick, in which there are, of course, no headers (p. 10). In thicker walls this arrangement is impracticable, because it gives no bond across the thickness of the wall.

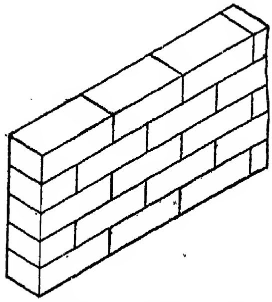


FIG. 32.—Stretcher Bond.

In **header bond** all the bricks are laid with their ends to the face of the wall. This bond is used chiefly for curved surface-work, where the faces of the stretchers (p. 10), if used, would, unless cut off, project beyond the surface of the wall at each end.

English bond, or, as it is sometimes called, **Old English bond**, consists of alternate header and stretcher courses on

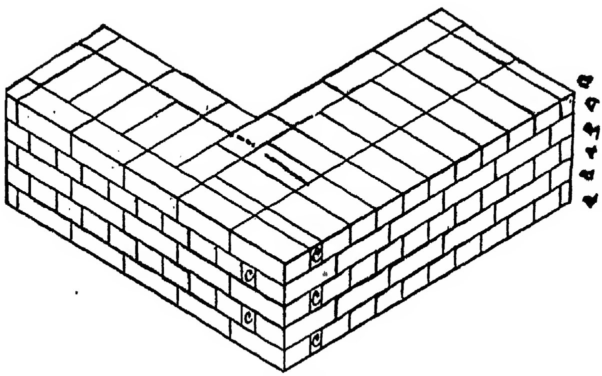
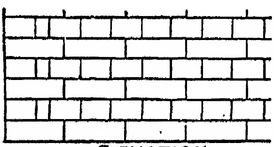


FIG. 33.—English Bond.

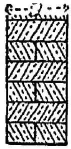
the face of the wall (Figs. 27 and 33). This bond, as well as Flemish (Fig. 55), requires the insertion of a **closer** (marked *c*, *c*) next the quoin-header, in order to get the necessary bond.

A point worth noticing in walls built in English bond is that if the wall is one, two, three, or any *whole* number of

bricks in thickness, stretcher or header bond appears on both sides in the same course (see Figs. 41 and 42). On the other



ELEVATION.



SECTION
FIG. 35.

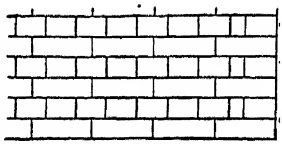
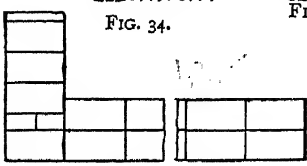


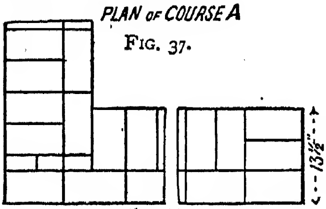
FIG. 36.

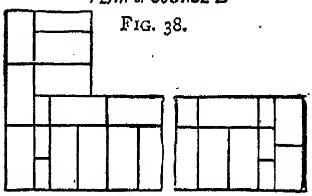
FIG. 34.



PLAN OF COURSE A
FIG. 37.

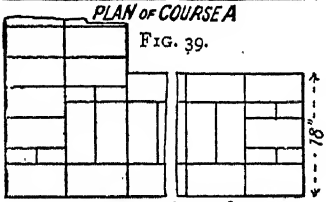
PLAN OF COURSE B
FIG. 38.

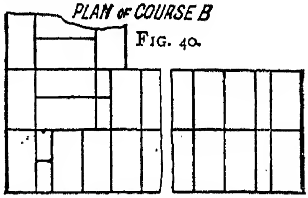




PLAN OF COURSE A
FIG. 39.

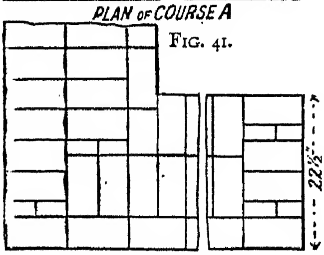
PLAN OF COURSE B
FIG. 40.

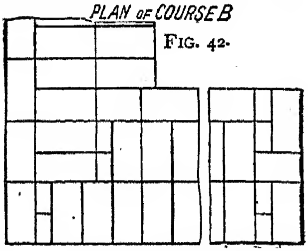




PLAN OF COURSE A
FIG. 41.

PLAN OF COURSE B
FIG. 42.





PLAN OF COURSE A
FIG. 43.

PLAN OF COURSE B
FIG. 44.

English Bond.

hand, if the wall is an *odd* number of *half* bricks thick (*e.g.* 1½, 2½, etc., bricks in thickness), the same course shows

headers on one side and stretchers on the other. A wall one and a half bricks thick is often referred to as a fourteen-inch wall, although its actual thickness is only thirteen and a half inches.

A modified form of English bond is frequently used in some parts of the country, especially where a superior quality of brick is used for the face of the wall. This consists of three courses of bricks laid as stretchers, to one course laid as headers. Such an arrangement effects a saving of facing-bricks, but does not give so perfect a bond as Old English.

Flemish bond may be single or double. It is *single* when

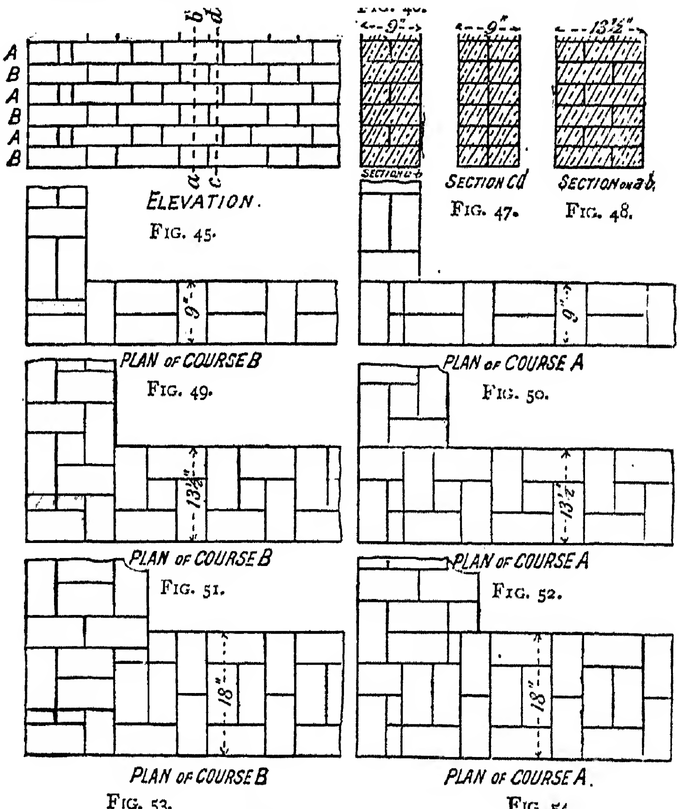


FIG. 45. FIG. 46. FIG. 47. FIG. 48. FIG. 49. FIG. 50. FIG. 51. FIG. 52. FIG. 53. FIG. 54.

Double Flemish Bond.

the bond is Flemish on one side and English on the other, and *double* when Flemish on both sides.

Flemish bond is formed by having header and stretcher

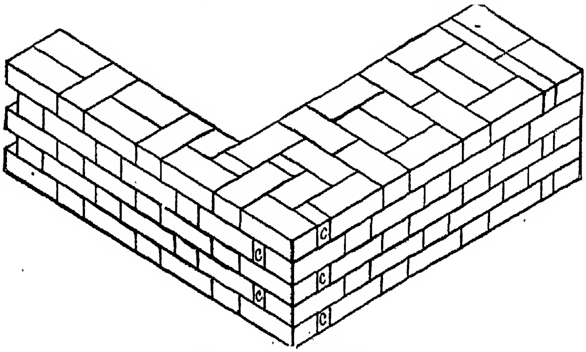


FIG. 55.—Flemish Bond.

alternately in the same course, the header in one course being placed across the middle of the stretcher in the course above or below it (Fig. 55). The closer must be inserted in alternate courses next the *quoin-header*, as in Fig. 55.

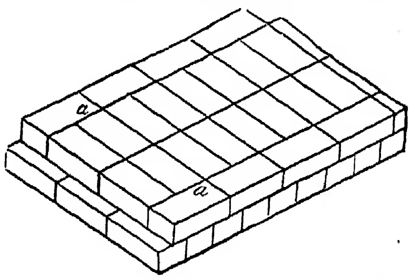


FIG. 56.—The joints across a wall should be continuous, as *a*, *a*.

Flemish bond, though not so strong as English, is considered to have a better appearance. Greater care is, however, required by the workman in order to keep the "perpends," that is, to keep each vertical joint in any one course directly over the corresponding vertical joint in the course next but one below. A neglect of this precaution detracts considerably from the appearance of the finished work.

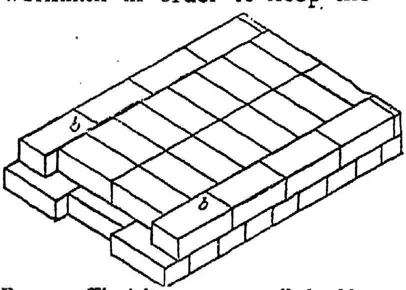


FIG. 57.—The joints across a wall should not break joint, as at *b*, *b*.

In the *inside* of all walls over one and a half bricks thick, all the bricks must be arranged as headers, that is, with the length of the bricks across the wall (Fig. 56). If stretchers are used (as shown in

Fig. 58, in courses marked *s*, *s*), although the bonding appears correct on the face, the wall is built up of two independent thicknesses without ties, as shown by the thick line. There is still, however, a lack of stretchers in the middle of the wall, and, as an additional tie, "**diagonal bond**" is frequently used at intervals of three or four courses. Diagonal bond is obtained by arranging the bricks at an angle of about 45° with the face of the wall.

In the same course the joints *across* the wall should be continuous, as in Fig. 56 (*a*, *a*), and should not "break joint," as shown in Fig. 57 (*b*, *b*).

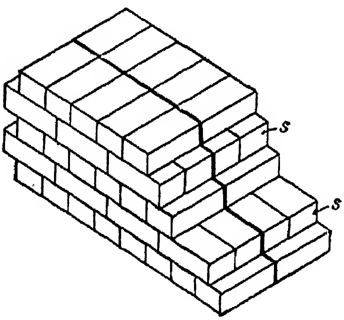


Fig. 58.—A wall built up of two independent thicknesses.

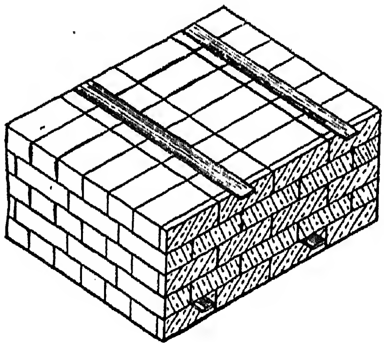


Fig. 59.—English Bond strengthened with hoop iron.

As an additional bond to strengthen thick brick walls, lengths of tarred and sanded hoop-iron, each from one and a half inches ($1\frac{1}{2}''$) to two inches ($2''$) wide, and one-sixteenth to one-eighth of an inch ($\frac{1}{16}''$ to $\frac{1}{8}''$) thick, are built in lengthwise, every four or five courses in height (Fig. 59). The joints at all angles and junctions are formed by folding the ends of the hoop-iron over each other.

Garden-wall bond.—Bricks vary more in length than in breadth. On this account, when in dwarf walls, boundary walls, etc., it is necessary to obtain a fair face on both sides of a nine-inch wall, it is of advantage to have considerably more stretchers than headers. When the bricks are arranged with three or four courses of stretchers between each course of headers, *English garden-wall bond* is obtained (see Fig. 60).

An alternate arrangement of three stretchers and one header in *each* course gives *Flemish garden-wall bond.*

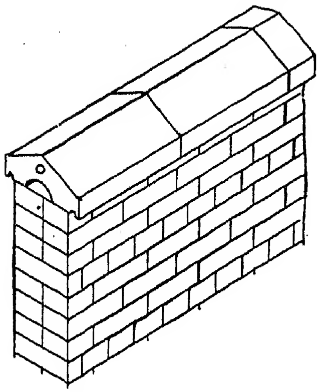


Fig. 60.—English-Garden-wall Bond with Saddleback Coping.

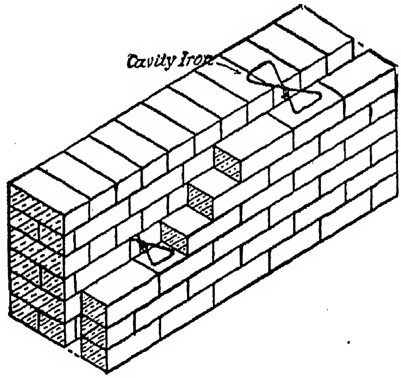


Fig. 61.—Cavity Wall.

Cavity walls are frequently formed in the erection of buildings. They consist of two separate walls, with an air space, varying from two inches (2″) to four and a half inches ($4\frac{1}{2}$″), generally three inches (3″), between them (Fig. 61). The object of such walls is to prevent the damp from getting through

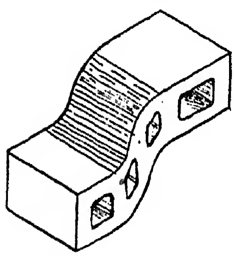


Fig. 62.—Bonding Brick.

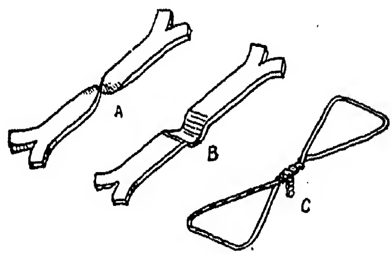


Fig. 63.—Cavity Irons.

the walls. They are tied together with special **bonding bricks** (Fig. 62), or **cavity irons** (Fig. 63, *A*, *B*, *C*).

When cavity walls are used, it is much the best plan to build the thicker wall on the inner side, as the floors, roof, etc., will of necessity be supported by the inner wall. Damp is also kept further from the interior of the building than would be the case with the reverse arrangement.

Foundations.—The walls at the base of a building should go to a sufficient depth below the surface of the ground to be unaffected by atmospheric influences. The wall should also be made wider at the base than it is at the ground level, in order to distribute the weight over a larger area of ground. The nature of the ground largely determines the width at the base, a building erected on a marshy site naturally requiring

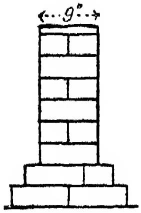


FIG. 64.

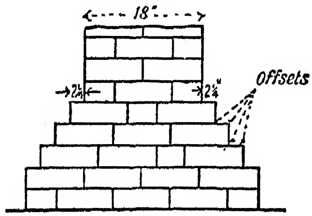


FIG. 65.
Brick Footings.

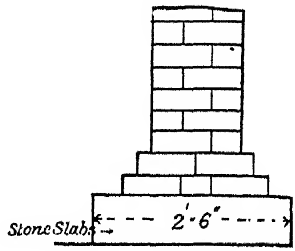


FIG. 66.
Stone Footings.

a wider foundation than the same building on ground of a rocky nature. As a general rule, in ordinary earth, a depth of three feet (3′) below the surface, and a width of the bottom courses equal to double the thickness of the wall at the ground level, are sufficient.

The foundations may be formed—

(*a*) By footings, that is, by spreading the wall by means of offsets (Figs. 64 and 65), each offset being two and a quarter inches ($2\frac{1}{4}''$), or a quarter-brick, with, in thick walls, the lowest two courses of equal width, as shown in Fig. 65.

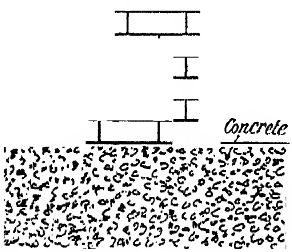


FIG. 67.—Concrete Foundation.

(*b*) By laying down rough thick stones of width equal to twice the thickness of the wall, and then forming offsets on these to distribute the weight of the wall on the stones, as in Fig. 66.

(*c*) By concrete composed of Portland cement, broken stones, and sand, mixed together with water. The material

thus produced, when properly made and deposited, becomes one solid mass as hard as stone. This method is preferable to the two preceding ones, and is being generally adopted. When concrete is used for foundations, its width should be equal to twice the thickness of the wall at the ground level, and its thickness from one-third ($\frac{1}{3}$) to one-half ($\frac{1}{2}$) its width. The lower courses of brickwork resting on the concrete may be spread, as shown in Fig. 68, or may be formed without offsets, as in Fig. 67.

In laying concrete, any unfinished part should be thoroughly wetted before the remainder is added. The concrete is also improved by being kept damp for some time, as this retards the setting and improves the ultimate strength of the foundation.

Damp-proof Course.—A damp-proof course is a layer of

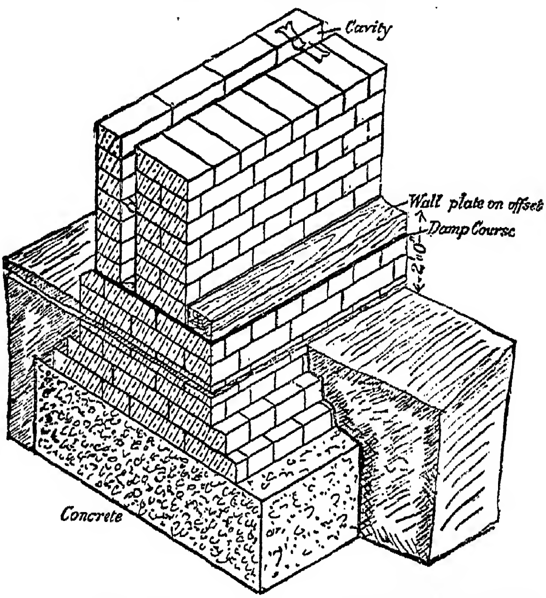


Fig. 68.—Sketch of Cavity Wall, showing Concrete Foundation, Damp-proof Course, etc.

impervious material, which should *never* be omitted in the erection of buildings. Its object is to prevent the damp from rising from the ground and getting into the building. It should be

laid on all walls just above the ground and below the floor level, as shown in Fig. 68. Materials suitable for damp-proof courses are: sheet lead; slates embedded in cement; asphalt, half an inch ($\frac{1}{2}''$) thick; Portland cement and sand, half an inch ($\frac{1}{2}''$) thick; pitch or gas-tar; Hygeian Rock; fireclay blocks (which form at the same time a damp-proof course and a ventilating course); or any material which does not allow moisture to pass through it.

Piers.—The piers or pillars of brickwork between window- or other openings should always be arranged of such a width that a perfect bond can be obtained with the bricks used. Thus, in Fig. 69 the distance from *a* to *b* should, if in English bond, be a multiple of the length of a brick (9″) in length; while, if Flemish bond be used, the distance should be arranged so that header and stretcher come alternately in the same course, and that each side of the pier finishes in each course either with stretcher or with header and closer. Any neglect of this precaution increases the cost of labour, and frequently spoils the appearance of the work.

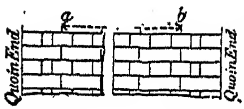


FIG. 69.—To illustrate distance between *a* and *b*.

Window or Door Openings.—These openings may have *square jambs*, or be provided with *reveals*.

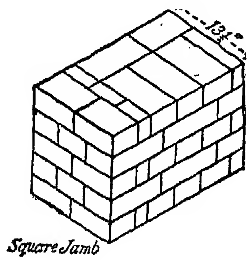


FIG. 70.—To explain Square Jamb.

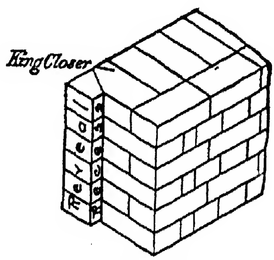


FIG. 71.—Reveal in Brickwork.

Square jambs are generally used for the inside openings in walls (Fig. 70). In window-openings and doorways a recess is formed, into which the frame is secured (Fig. 71). The projecting face of this is known as the **reveal.** In brickwork the reveal may be four and a half inches ($4\frac{1}{2}''$), nine inches (9″), or any multiple of half-bricks deep, and the

recess two and a quarter inches ($2\frac{1}{4}''$) or four and a half inches ($4\frac{1}{2}''$) wide, these dimensions being necessary to obtain proper bonding of the bricks. It is sometimes desirable to have rounded or chamfered corners to the quoin bricks of the reveal in a doorway. When this is the case, splayed or bull-nosed bricks are used. These bricks are of ordinary size, but have one end formed as shown in Figs. 72 and 73.

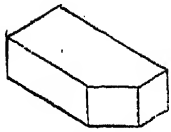


FIG. 72. Splayed Brick.

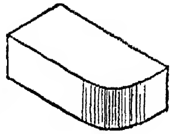


FIG. 73. Bull-nosed Brick.

Arches.—The top of an opening may be formed by means of an arch or by a stone lintel or head. Arches may be gauged, rough-axed, or plain, according to their position in the building.

Gauged arches are used for the outside openings of superior buildings. In these the bricks (which are selected for their even texture and softness) are cut and then rubbed to the required shape, so that all the joints radiate from the centre, and are of the same thickness as the joints in the remainder of the work. Such arches require great care in construction, as if, to save labour of rubbing, the bricks are cut thinner at the back than at the front in order to get a fair joint on the face, the arch has a tendency to bulge. To obviate this it is better to have specially moulded bricks for all arches.

Rough-axed arches are used for inferior outside work, and over openings inside buildings where they will be afterwards covered in the plastering, or otherwise hidden from view. They are formed with ordinary bricks, roughly cut to the required shape, the joints being from three-sixteenths of an inch ($\frac{3}{16}''$) to three-eighths of an inch ($\frac{3}{8}''$) thick.

Plain arches are those formed with bricks used without any cutting whatever, such as the relieving arch over the wooden lintel or beam which carries the inner part of the wall above a window-opening or doorway, and the inverted arches used to distribute the weight of the building over a larger area. Unless the radius of the arch be large, it is advisable to build all such arches in $4\frac{1}{2}''$-brick rings, as shown in Figs. 79 and 81 (*A*).

Forms of Arches.—Arches are named from the outline of their **soffit or underside**, as flat (Fig. 76), segmental (Fig. 74), or semicircular (Fig. 75). Relieving arches (Fig. 79), French or Dutch arches (Fig. 83), and inverted arches (Fig. 84), are other types. For the names of the various parts of an arch, see Fig. 77.

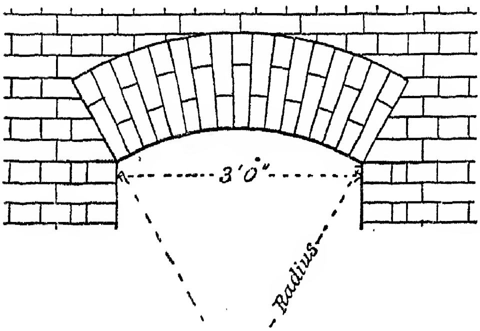


FIG. 74.—Segmental Arch.

Straight arch.—An arch of this description, when used for an outside window-opening or doorway, is generally finished as a gauged arch (Fig. 76), and though it is apparently flat on the soffit, it has a **rise or camber** equal to about one-eighth of an inch ($\frac{1}{8}''$) for every foot of width of opening, in order to prevent it from being hollow when the arch settles. This arch should be equal in depth to three or four courses of bricks. Such an arch is best built of specially made bricks, each one being the full length; if, however, as is often the case, ordinary bricks are used, they are cut and rubbed to the required shape. Fig. 78 shows in detail the method of drawing this arch, and of obtaining the shape of the bricks when constructed

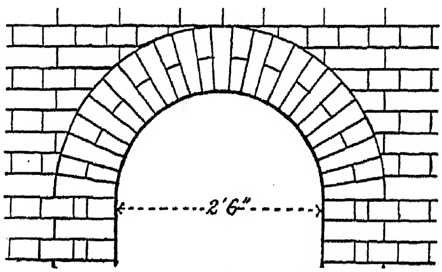


FIG. 75.—Semicircular Arch.

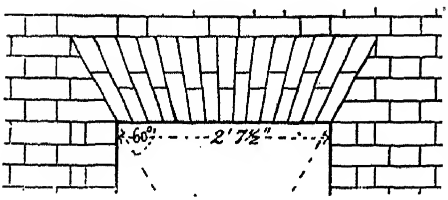


FIG. 76.—Straight-gauged Arch.

with ordinary bricks. The angle AAC equals the slope of the skewback (usually 60°); ab, cd, ef are each equal to the thickness of the bricks used (3″); lines drawn from b, d, f, towards

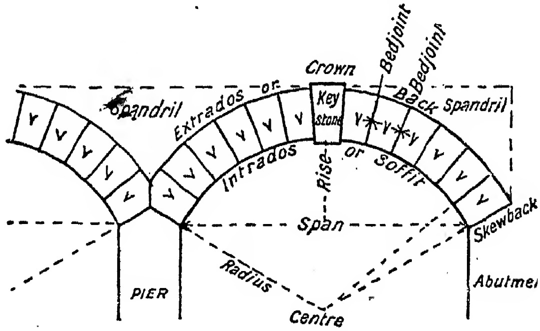


FIG. 77.—Parts of an Arch. The arch blocks VVV, are named Voussoirs.

C, until they meet AA, give the bed-joints; draw gh parallel to ab, measure hk equal to the length of a brick (9″), and

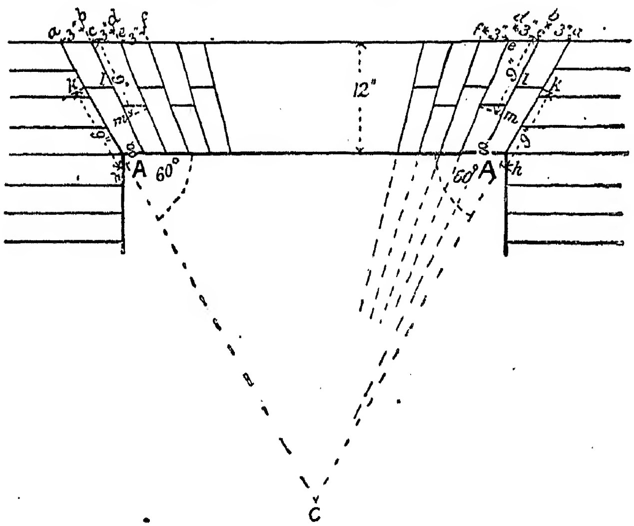


FIG. 78.—Construction of a Straight-gauged Arch.

from the point k draw the horizontal line kl; then kl is the first horizontal joint. The second is drawn by taking cm equal to 9″. The third, fifth, etc., are in the line of the first

while the fourth, sixth, etc., are in the line of the second. Near the centre of the arch the distance is equally divided (as near 3″ as possible), taking care to have one central brick, that is, an odd number of bricks in the arch.

A straight-gauged arch, when used as above, only

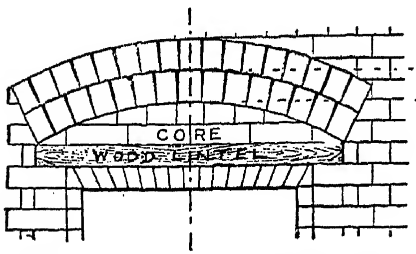


FIG. 79.—Wood Lintel with Relieving Arch.

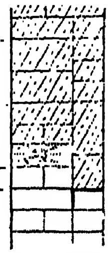


FIG. 80.—Section.

provides for the outer portion of an opening, the inner wall being carried by a plain (Fig. 81, *A*) or rough-axed arch (Fig. 81, *B*), or supported by a lintel of wood, the thickness of which may be taken as 1″ for every foot of open-

is formed a rough brick relieving or discharging arch in two half-brick rings (Figs. 79 and 80), the object being to prevent collapse in case of the destruction of the lintel by fire or rot. The brickwork which is on the top of the lintel and under the relieving arch is named the **core.** Concrete lintels are frequently used in place of wooden ones.

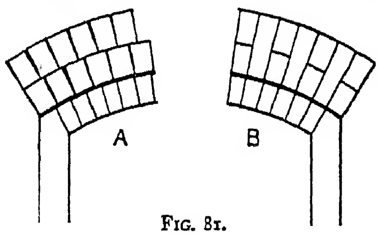


FIG. 81.

A. Plain Arch in half-brick rings. *B.* Rough-cut or axed Arch.

Segmental arch.—The method of getting the outline of a segmental arch involves a slight knowledge of geometry, that is, to the extent of determining a curve to pass through three given points. The method is as follows: Take as

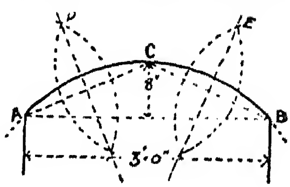


FIG. 82.—Method of obtaining outline of a Segmental Arch.

example an opening 3′ 0″ wide, with a rise in the centre of 8″ (Fig. 82); mark the points A, B, C in the required curve, the point C being in the centre. Join AC, BC. Bisect the lines AC, BC by the lines DO, EO at right angles to AC, BC respectively. The point O in which DO, EO meet is the centre of the circle of which ACB is the segment required.

Segmental and semicircular arches may be nine inches (9″), fourteen inches (14″), or any multiple of half-bricks in depth on the face, according to the class of work, width of opening, etc. These arches may extend through the thickness of the wall, or, where a reveal is formed, as in window-openings or doorways, be restricted to the face. In the latter case the inner wall is supported on a plain (Fig. 81, A) or rough-axed arch (Fig. 81, B).

French or Dutch arch.—Another form of arch sometimes used for inside openings of narrow span is the French or Dutch arch (Fig. 83). This arch, however, is not suitable for large spans, and is of weak construction.

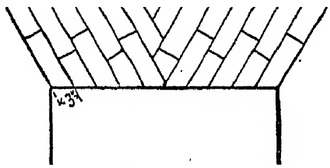


FIG. 83.—French or Dutch Arch.

Inverted arches.—When a number of openings occur on the ground floor of a building it is often advisable, in order to distribute the weight over a larger area, to use inverted arches between the piers (Fig. 84). Such inverted arches are almost invariably built in half-brick rings, and set in cement mortar.

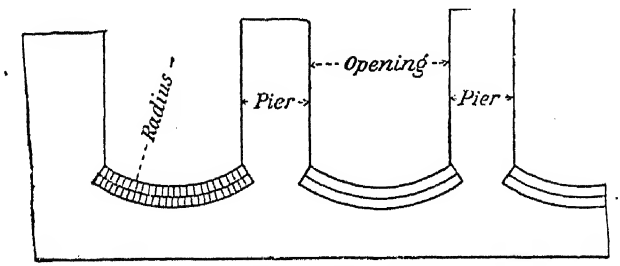


FIG. 84.—Inverted Arches.

Trimmer arches are formed under hearth-flags where

fireplaces occur. They will be more fully explained in the chapter on floors (see Fig. 218).

Centres.—Rough wooden centres of outline to suit the soffit of the arch are required to temporarily carry brick arches during their construction. They should, however, be eased as soon as the arch is completed, to allow the usual slight settlement to take place. The shape and method of construction of these centres vary according to the shape and size of the arch. Their construction will be dealt with in a later chapter.

Fixings.—When erecting buildings it is always economical to provide means for fastening any woodwork, such as door-frames, window-linings, etc., that may be afterwards required.

This may be done by building in, as the work proceeds, wood blocks, with the end grain of the wood vertical. A convenient size for such blocks is four and a half inches ($4\frac{1}{2}''$) by four and a half inches ($4\frac{1}{2}''$) by the thickness of a brick *plus* two mortar-joints. Thus if the bricks used were three inches ($3''$) thick, with mortar joints each a quarter of an inch ($\frac{1}{4}''$) thick, the blocks would require to be three and a half inches ($3\frac{1}{2}''$) long. Such blocks are not so liable to become loose as those of the size of ordinary bricks built in with the grain of the wood horizontal. An alternative is to build thin slips of seasoned wood, about three-eighths of an inch ($\frac{3}{8}''$) thick, between the joints of the brickwork.

Breeze bricks, made from Portland cement and coke-breeze, are frequently used instead of the above wood blocks. The advantage in using them lies in the fact that they are not affected by damp or liable to decay. Wood plugs are also extensively used for fixing woodwork in buildings. These should be cut with the axe, and have twisted surfaces, as shown in Fig. 85. They should not be sawn, as in Fig. 86.

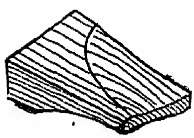


FIG. 85.

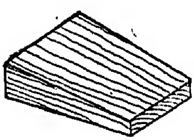


FIG. 86.
Wood Plugs.

Copings.—Copings are used on the tops of walls to protect them from the weather. The copings may be formed of bricks, stone, concrete-blocks, terra-cotta, etc. When copings are of brickwork, the hardest bricks only should be used, and they should be set in cement-mortar, to render the top of the wall waterproof.

Figs. 87 and 88 show copings formed with bricks of ordinary size. The courses *a*, *a* are called *oversailing courses*

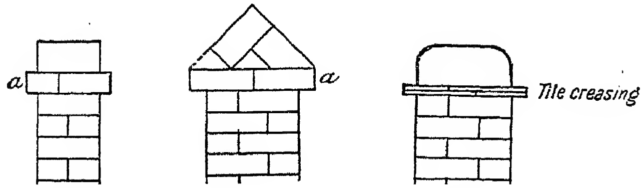


FIG. 87. FIG. 88. FIG. 89.

Sections of Copings.

The coping shown in Fig. 89 is made from specially moulded bricks. In this case the oversailing course consists of two or three thicknesses of tiles, and is known as "tile-creasing."

Terra-cotta is extensively used for copings. Fig. 60 shows what is known as a "saddleback" coping on a nine-inch (9″) wall. Copings are, however, made to many other designs, both in stone and terra-cotta.

SUMMARY OF CHAPTER

The two kinds of **bond** in general use are English and Flemish.

English bond consists in alternating a course of headers with a course of stretchers.

In **Flemish** bond the stretchers and headers alternate with each other in every course. Neither English nor Flemish bond can be formed without the use of closers.

The **closer** is always placed next the quoin *header*.

Garden-wall bond is used for walls 9″ thick where it is necessary to have a good face on both sides; it is obtained by having three courses of stretchers to each course of headers if English, and by having three stretchers to one header in each course if Flemish.

Cavity walls are so named because they are formed by building two separate walls with an air-space or cavity between them. They are tied together by bonding-bricks or cavity irons.

Foundations are necessary in all buildings, and most kinds of ground require the walls to be spread in order to distribute the weight over a greater area. They may either be formed entirely from bricks, or concrete may be used.

A **damp-course** is necessary just above the ground level and below the floor line. It should be formed of material through which damp cannot pass.

Window- and door-openings may have square jambs or reveals.

The tops of such openings may be formed with brick arches, which are named according to the outlines of their soffits.

Arches may be *plain*, *rough-axed*, or *gauged*, according to their position in, and the nature of, the building. Other arches used in special positions are the relieving or discharging arch, French or Dutch arch, inverted arch, trimmer arch, etc.

Wooden or breeze bricks, thin slips of wood built in the joints, or wooden plugs, afford a means of securing woodwork to brick and stone walls.

Copings are placed on the tops of walls to protect them from the weather.

QUESTIONS ON BRICKWORK

("Starred" questions are supplied with Figures.)

1. Draw the elevation of six courses of brickwork at the stopped end of a wall, showing the bricks arranged in English bond. Draw also the plans of two successive courses when the wall is 9″, 13½″, and 18″ thick respectively. Scale, 1″ to the foot.

2. Draw the elevation of eight courses of brickwork, with the bricks laid in Flemish bond. Project from this elevation the plans of two successive courses when the wall is (*a*) one brick, (*b*) one and a half bricks, (*c*) two bricks, thick. Scale, $\frac{1}{12}$ full size.

3. Draw vertical cross sections through the foundations of brick walls 9″, 14″, and 18″ thick respectively, built in English bond, showing in each case the footings composed entirely of bricks. Scale, 1½″ to the foot.

4. Draw a vertical cross section through the lowest part of a two-brick thick wall (Flemish bond), with concrete foundation: the width of the concrete being 3′ 0″, and its depth 1′ 4″. Scale, $\frac{1}{12}$ full size.

5. Draw the front and end elevations (of about six feet in length) of a brick boundary wall 3′ 6″ high and 9″ thick, and surmounted by a saddleback coping; the bricks to be arranged in English garden-wall bond. Draw also the plans of two consecutive courses. Scale, ¾″ to the foot.

6. Draw an isometric sketch of eight courses at the angle of a brick building, the walls of which are 9″ and 14″ thick respectively, and built in English bond. Draw also the plans of the uppermost and lowest courses of the same. Scale, 1″ to the foot.

7. Draw an isometric sketch of six courses at the angle of a brick building in English bond, the walls of which are two bricks and two and a half bricks thick respectively. Draw also the plan of the second course from the top, and a vertical cross section through the thicker wall. Scale, ¾″ to the foot.

8. Repeat question (6)
bond.

9. Draw a vertical cross-section through the foundations of a 16″ cavity wall, showing concrete foundation, damp-course, and the walls tied together with cavity-irons: the thicker part (9″) to be on the inside. Scale, 1″ to the foot.

10. Draw the outside elevation of the upper part of a doorway, 3′ 0″ wide, in a brick wall in English bond, showing the opening surmounted by a segmental gauged arch 9″ deep, with a rise of 6″ at the centre. Scale, $1\frac{1}{2}$″ to the foot.

11. Draw, to a scale of 1″ to the foot, the outside elevation of a semicircular arch one and a half bricks deep over an opening 3′ 0″ wide. Fill in the joints of the surrounding brickwork in Flemish bond. Project from this a vertical cross section through the crown of the arch, showing the wall 9″ thick.

* 12. The figure is the plan of a window-opening in a brick wall built in English bond.

Fig. 90.

Draw, to a scale of 1″ to the foot, the outside and inside elevations of the upper part of the opening, adding on the outside a straight-gauged arch, and on the inside a wooden lintel with a brick relieving arch in two half-brick rings.

Project from the front elevation: (*a*) a vertical cross-section through the opening; (*b*) the plans of two alternate courses, showing the bonding of the bricks at the reveals (Fig. 90).

13. Draw the plans of two alternate courses on one side of the window-opening of question 12, when the wall is (*a*) 18″ thick, with 9″ reveal and $4\frac{1}{2}$″ recess; (*b*) 18″ thick, with 9″ reveal and $2\frac{1}{4}$″ recess. Scale, $1\frac{1}{2}$″ to the foot.

Examination Questions

* 14. Plans of two successive courses of a brick pier (Fig. 91).

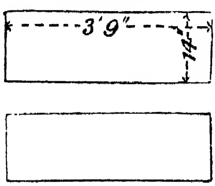


Fig.

Draw, to scale of 1″ to a foot, showing the bricks laid in English bond.

* 15. Plan of part of one course in a $2\frac{1}{2}$-brick wall built in English bond (Fig. 92).

Draw, to scale of 1″ to a foot, making any alteration you think necessary, and showing by dotted lines, on the same plan, how the bricks should be arranged in the next course.

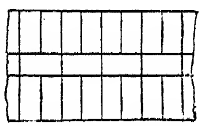


Fig. 92.

* 16. Part elevation of both the end and face of a brick wall built in Flemish bond (Fig.

Draw, to scale of $\frac{3}{4}''$ to a foot, filling in the joints of the bricks by single lines.

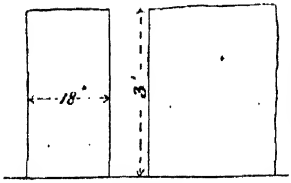


FIG. 93.

*17. Plans of two consecutive courses at the end of a brick wall built in Flemish bond (Fig. 94).

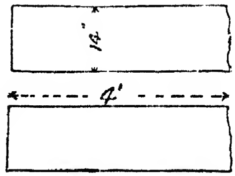


FIG. 94.

Draw, to a scale of $\frac{1}{12}$, showing the joints of the brickwork, and marking by thick lines any portions of the joints which run unbroken down the wall.

*18. Plan *A* represents one course at the end of a brick wall built in Flemish bond (Fig. 95).

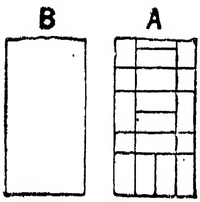


FIG. 95.

Draw, to a scale of $1''$ to a foot, making any alteration you think necessary. Also draw plan *B*, showing the arrangement of the bricks in the next course.

*19. Plans of two courses of brickwork at the angle of a building built in English bond (Fig. 96).

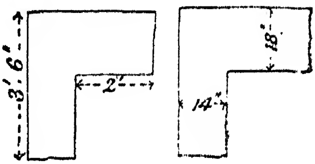


FIG. 96.

Draw, to a scale of $\frac{3}{4}''$ to a foot, showing the joints by single lines, and marking by thicker lines those portions of the joints which run unbroken down the wall.

*20. Plan of the angle of a brick building built in English bond (Fig. 97).

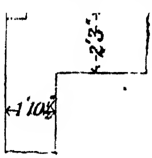


FIG. 97.

Draw, to a scale of $\frac{1}{2}''$ to a foot, showing the joints of the bricks by single lines.

*21. Plan of a course of brickwork at the angle of a wall built in single Flemish bond (Fig. 98).

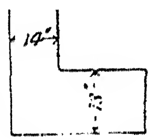


FIG. 98.

Draw, to a scale of $1''$ to a foot, showing a heading course on the inner face of the wall.

*22. Plan of part of a brick wall at ground level, showing the footings and $9''$ concrete foundations, the total depth below the surface being $2' \ 6''$ (Fig. 99).

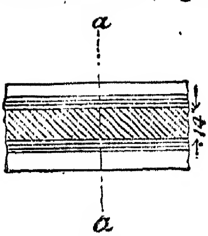


FIG. 99.

Draw, to a scale of $1''$ to a foot, a section through *a—a*, showing the joints of the brickwork by single lines.

* 23. Section showing the footings of a brick wall resting on a bed of concrete 2′ thick (Fig. 100).

Draw, to a scale of ¾″ to a foot, showing the joints of the brickwork in English bond, and making any alteration you think proper.

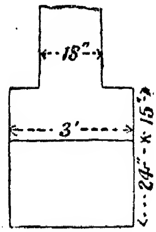


FIG. 100.

* 24. Plan of part of an 18″ brick wall built in English bond, showing also the width of the bottom course of footings (Fig. 101).

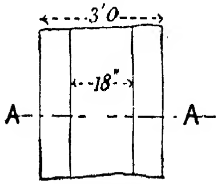


FIG. 101.

Draw the plan, to a scale of ¾″ to a foot, filling in the bricks in the 18″ course only. Draw a vertical section through *A*—*A*, showing the arrangement of the bricks in the footings, no offset to be more than a ¼-brick.

* 25. Vertical section through the footings of an external wall of a dwelling-house, the brickwork resting on the soil (Fig. 102).

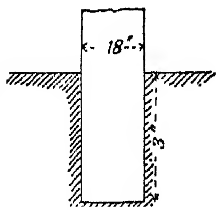


FIG. 102.

Draw, to a scale of ½″ to a foot, making any alteration to the footings you think necessary, and showing the bricks laid in English bond. Nothing but brickwork to be shown.

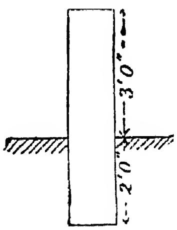


FIG. 103.

* 26. Section of a dwarf brick wall (Fig. 103).

Draw, to a scale of ¾″ to a foot, showing the joints of the brickwork below the ground, adding the footings and a proper stone saddleback coping 17″ wide.

* 27. Elevation of a 9″ arch ring, over an opening in a brick wall built in Flemish bond. Span of arch 6′, and rise 12″ (Fig. 104).

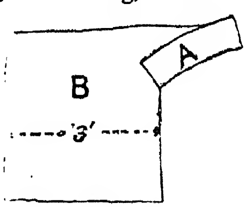


FIG. 104.

Draw, to a scale of ¾″ to a foot, showing four courses of the arch bricks at *A*, and four courses of the wall bricks at *B*.

* 28. A semicircular opening in a brick wall

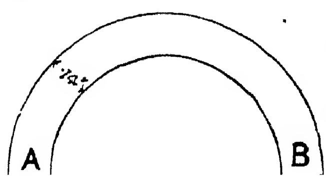


FIG. 105.

Draw, to scale of 1½″ to a foot, showing at *A* six courses of a plain or rough arch; at *B*, four courses of an axed or rough-cut arch.

External elevation of a window-opening in a brick wall (Fig. 106).

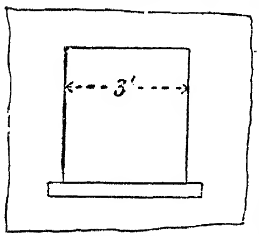


FIG. 106.

Draw, to a scale of 1″ to a foot, the head of the same, showing a straight-gauged arch, and giving all the joints of the bricks composing it.

30. Draw, to a scale of $\frac{1}{12}$, the back elevation of the head of a 3′ window-opening in a brick wall, with $4\frac{1}{2}$″ reveals, a plain stone head, wood lintel, and common discharging arch. The joints of the brickwork to be shown only on the right half of the elevation. The bond to be English.

*31. Elevation of the head of a door-opening filled in with a common flat arch, used in inferior work, and known as a French or Dutch arch (Fig. 107).

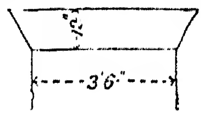


FIG. 107.

Draw, to a scale of $\frac{1}{12}$, showing by single lines the joints of the bricks forming the arch.

32. Draw, to a scale of $\frac{1}{12}$, an elevation of a rough inverted arch in two half-brick rings, for a 4′ opening, distributing the pressure over a concrete foundation.

CHAPTER III

STONEWORK

Dimensions of Stones employed. — Stones used for building purposes differ from bricks in being of unequal shape and size; in consequence of which, more skill is required in building in order to obtain a good bond.

To guard against fracture being caused by settlement, the length of the block should not, in the harder class of building stones, exceed four or five times, nor the breadth be more than two or three times, the thickness. In the softer kinds of stone the length should not exceed three times the thickness, while the breadth may be from one and a half times to twice that measurement.

Natural Bed.—Most building stones are obtained from rocks which have a distinct plane of division, whether of jointing or cleavage, along which the stones are split when obtained from the quarry. These planes of division should be horizontal in wall stones, or at right angles to the pressure to which they are subjected. In arches the planes of division should be at right angles to the pressure of the arch. Stones so placed are said to be **laid on their natural bed.** Should this precaution be neglected, the damp may get in between the layers and split the stones.

Bond in stone, as in brickwork, is the arrangement of the blocks so that they overlap each other.

Different kinds of Stone-walling: Random Rubble (Fig. 108, *A*), and **Random Rubble built up to Courses** (Fig. 108, *B*).—These arrangements only differ from each other in that the latter has the work brought to a level at distances varying from twelve to fifteen inches (12″ to 15″) in height.

Walls built according to either plan are formed by using stones of all shapes and sizes, and building them together so that a good *bond* is obtained. Greater skill is required to build this class of wall than any other, as the stones, being of irregular shape, are difficult to bed. Three or four courses of brickwork are sometimes inserted in random rubble walls in order to strengthen the bond. Such courses are called **lacing courses.**

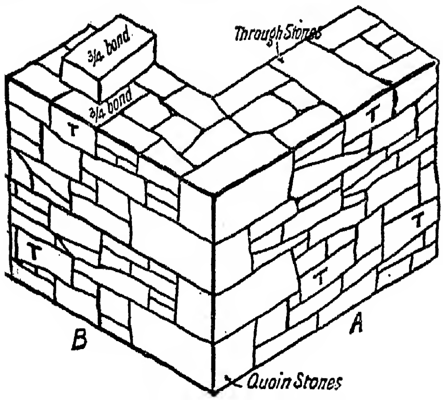


FIG. 108.—*A.* Random Rubble. *B.* Random Rubble built up to Courses.

The bonding together of the *thickness* of the wall is an important point and requires attention; it should be done by inserting **through stones** at intervals of four to five feet (4′ to 5′) horizontally, and fifteen to eighteen inches (15″ to 18″) vertically. These through stones may go quite through the thickness of the wall, but when so arranged in exposed situations they tend to conduct dampness into the inside. A better plan is for these *bond stones*, for such the through stones are, to extend through about three-quarters of the thickness only, as shown in Fig. 108. In this case two overlapping bond stones, that from the inside face of the wall being uppermost, are used together. Bond stones should be of sufficient thickness to prevent danger of fracture through any slight settle-

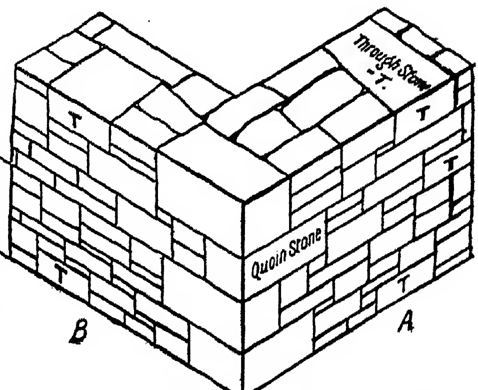


FIG. 109.—*A.* Irregular-snecked or Uncoursed Squared Rubble. *B.* Squared Rubble built up to Courses.

ment of the wall. In Figs. 108, 109, and 110, *T*, *T*, *T* show the positions of bond stones in a wall.

Squared Rubble: Irregular-snecked or Uncoursed Squared Rubble (Fig. 109, *A*); **Squared Rubble built up to Courses** (Fig. 109, *B*).—Both these arrangements are superior to the random rubble. In each of these cases the wall is built of rectangular stones with squared ends. The larger stones are laid first, and the spaces between them afterwards filled up with the smaller stones. When built up to courses, the wall is brought to a level every twelve to fifteen inches (12″ to 15″).

Coursed Rubble is a kind of walling extensively adopted. In it the stones vary in thickness from two inches to eight inches (2″ to 8″), and are sorted or **coursed** before the building commences. They are then built in courses, every stone in the same course being of the same thickness (Fig. 110).

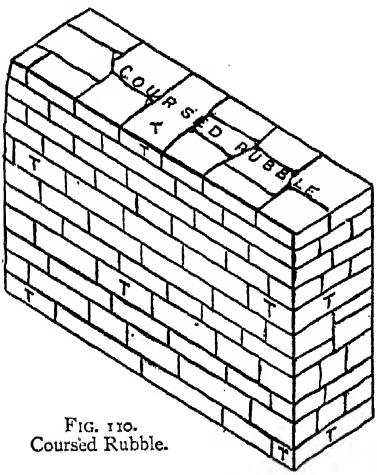
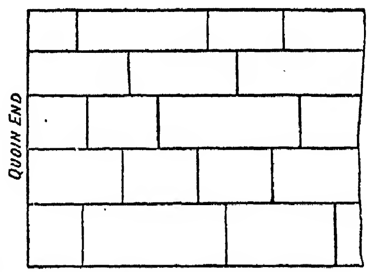


FIG. 110.
Coursed Rubble.



ELEVATION OF BLOCK-IN-COURSE.
FIG. 111.

Block-in-course is a class of work arranged in courses varying from eight to twelve inches (8″ to 12″) in thickness, and is especially suitable for heavy engineering works (Fig. 111). It differs from coursed rubble only in the greater size of its stones.

Ashlar.—Ashlar is the most expensive kind of walling, and is only employed in superior buildings. The stones used are built

in courses, and vary from ten to eighteen inches (10″ to 18″) in thickness. Each stone used must have five out of the six faces worked straight and true. The joints in ashlar walls are seldom more than an eighth or three-sixteenths of an inch ($\frac{1}{8}''$ or $\frac{3}{16}''$) thick. The face of the wall in this class of work may be plain-tooled or polished; the resulting surface when so finished is, however, rather monotonous in appearance, and is often relieved by **chamfering** the arrises, as at *A* (Fig. 112), or by **rebating** them, as at *B*. No stone for ashlar walls ought to have a width of bed less than the depth of the face.

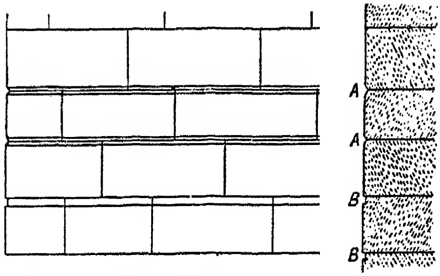
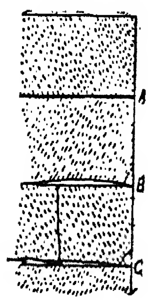


FIG. 112.—Ashlar Walling, showing: at *A* Chamfered Arrises; at *B* Rebated Arrises.

The expense attached to building thick walls with both sides ashlar-faced is so great that it is seldom incurred; the backing is built up of rubble or brickwork instead. There is a danger, however, when this is done, of unequal settlement taking place. This settlement is due to the larger number of mortar-joints in the inside of the wall than on the outside. Such unequal settlement causes bulging of the wall; it can, however, be guarded against to some extent by the use of through stones, and by setting the brick or stone backing in cement-mortar. It is also advisable to carry up both the front and back parts of the wall at the same time.

In the joints of ashlar masonry the bed-joints should be squared through the stone, as at *A* in Fig. 113, to prevent pieces (called **spalls**) from chipping off the face, as would be the case if the bed-joints were worked hollow, as at *B*, or slack on the back, as at *C*.



effects of hollow bed-joint (*B*), or if slack behind (*C*).

Ashlar Dressings.—Ashlar blocks are extensively used in combination with rubble walling or brickwork for forming quoin stones, window heads and

sills, door jambs, stone arches, string courses, plinths, copings, cornices, etc. Their surfaces are finished in various ways. They may be sawn, plain-tooled, or polished for window heads, sills, string courses, cornices, etc.; while for quoin stones, plinths, etc., the face is often finished with a worked, or, as it is sometimes called, a *drafted margin* around the edges, the central part being left rough, rusticated (Fig. 115, *B*), or with a punched surface, as in Fig. 114, *A*.

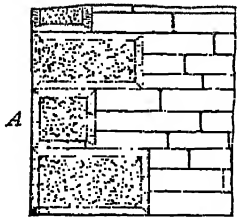


FIG. 114.
Quoin Stones with Drafted Margins and Punched Surface.

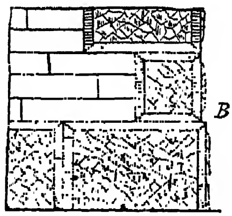
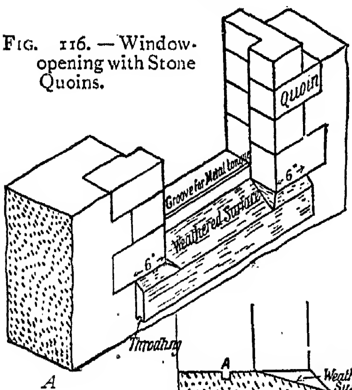


FIG. 115.
Quoin Stones with Drafted Margins and Rusticated Surface.

Quoin Stones are the corner stones either at the angles of a building (Figs. 108 and 109) or at the jambs of window- or door-openings (Figs. 116 and 118). They may be of the same thickness as the courses of stone, or, as is frequently the case, may be made from dressed ashlar of larger size. They should bond with each other as headers and stretchers (p. 10) alternately, and when used in conjunction with brickwork, should be made equal in thickness to a number of courses of bricks.

FIG. 116.—Window-opening with Stone Quoins.



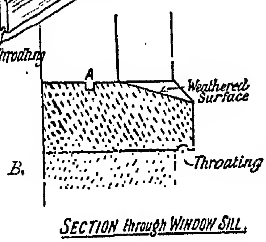


FIG. 117.

Window Sills.—Window sills placed in openings in brick walls should be equal in thickness to a number of courses of bricks *plus* mortar-joints; their lengths should be twelve inches (12″) greater than the width of the opening. This allows six inches (6″) at each end of the sill to form the

seating or *stool* for the jamb to rest upon. The upper surfaces of all window sills should be **weathered**, that is, their surfaces should slope sufficiently for water to flow off. The front edge of the under side of all window sills should be formed with a groove, or be **throated**, as it is called, to prevent water from running along the under side, and so getting into the wall (see Figs. 117 and 121).

A groove half an inch wide and half an inch deep should be cut into the stone on its upper surface (Fig. 117, *A*). Into this groove a metal tongue, which also fits a corresponding groove in the under side of the window frame, is placed.

In fixing window sills, mortar should be placed under the ends only, that is, the sills should be left hollow in the middle. This prevents the breaking of the sill by any settlement, which may result from the additional weight on the seat of the sill at each end.

Window Heads.—When the head of a window- or door-opening is made of stone, a stone relieving or discharging arch is sometimes built over it to take part of the weight from above (Fig. 118). It is more frequently, however, made deep enough to carry *all* this weight itself. When stone heads, or lintels,

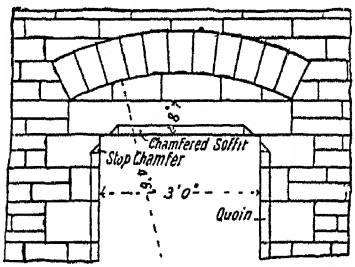


FIG. 118.—Elevation of upper part of opening in a Stone Wall, showing Chamfered Stone Head with Discharging Arch, Chamfered Quoins, etc.

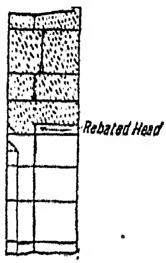


FIG. 119. Section.

are used in brick walls, they should be made equal in depth to a definite number of courses of bricks. Such stone heads may have the face and soffit (under side) plain and square (Fig. 120); or they may have the lower arris chamfered (Fig. 118); or the soffit may be curved (Fig. 122) or otherwise ornamented to improve the appearance. As regards the thickness—that of

the head may be equal to the width of the reveal only

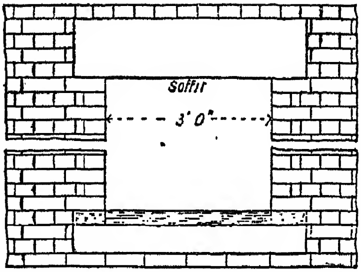


FIG. 120.—Elevation of opening in Brick Wall, showing Stone Head and Sill.

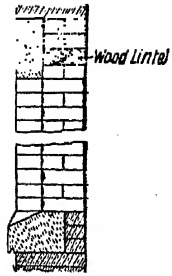


FIG. 121. Section.

(Fig. 121); or it may be thicker, and have the back part of the soffit rebated (Fig. 119). In certain styles of architecture, window-openings are subdivided into smaller openings, as shown in Fig. 122. In such cases the median horizontal stone, which is weathered on the upper surface, is called the **transom**. The vertical member is named a **mullion**.

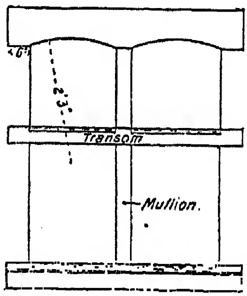


FIG. 122.—Window-opening with Mullion and Transom.

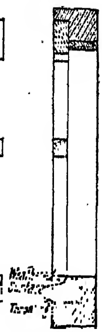


FIG. 123. Section.

Stone Arches.—The various parts of a stone arch are named in a similar way to those of brick arches (see Fig. 77). In segmental and semicircular arches the *voussoirs* may be of uniform size and shape,

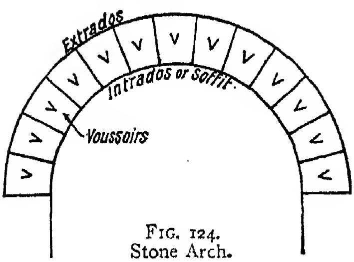


FIG. 124. Stone Arch.

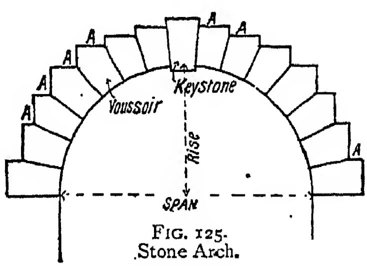


FIG. 125. Stone Arch.

as in Fig. 124, or the *extrados* of the voussoirs may be cut as

shown in Fig. 125. If used with brickwork, the steppings at *A*, *A*, Fig. 125, are of depth to suit the courses of bricks.

Rough arches may be formed with stone exactly as explained for brickwork.

String Courses are the long horizontal bands of stone, inserted in a building, usually at the upper floor or sill level, either for ornament or as an additional bond. They may be

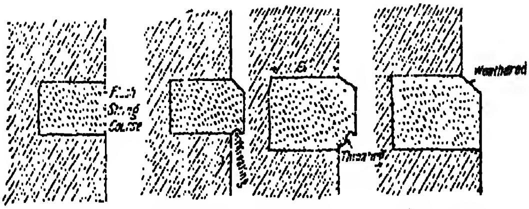


FIG. 126. FIG. 127. FIG. 128.
Sections through Stone String Courses.

FIG. 129.
Section through Stone Plinth.

flush with the rest of the wall (Fig. 126), or they may project from one to three inches (1″ to 3″) beyond the face of the wall. In the latter case the projection on the upper side is weathered (p. 38), and the under side throated or moulded (Figs. 127 and 128).

A **Plinth**, which may be formed either in stone or brick, is approximately at the level of the ground floor. It is a projecting base inserted both as a convenient means of diminishing the thickness of the wall and also as a source of strength. The upper arris may be weathered or moulded. Fig. 129 shows a section of a stone plinth which is weathered.

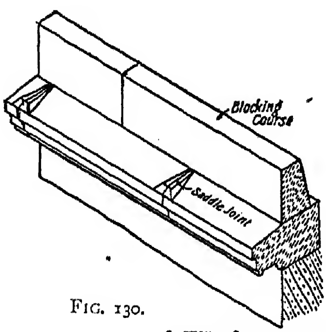


FIG. 130.

SKETCH of CORNICE & BLOCKING COURSE.

Copings are, as explained in the chapter on brickwork, used to protect the tops of walls from the weather. The coping on a pillar or pier is named a **capital**. The coping on the top of a chimney is named a **cap**.

Cornices take the place of copings in superior buildings. They are generally

moulded, and are frequently surmounted by a stone blocking course (Figs. 130 and 131).

The upper side of a cornice is weathered, except at the joints, which, therefore, project above the level of the weathered surface. Water is thus prevented from finding its way through the joints and running down the wall. Such joints are known as **saddle joints**

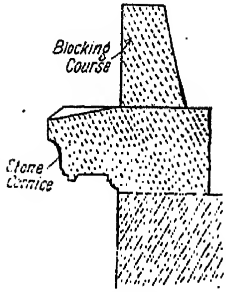
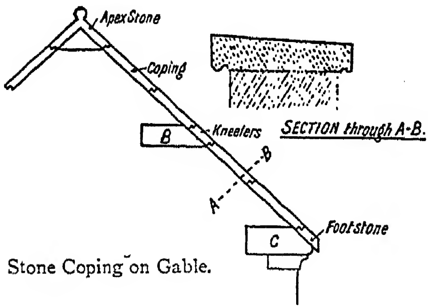


FIG. 131.—Section through Stone Cornice, Blocking-course, etc.

Gables.—When the wall forming a gable rises above the roof, it is protected by a coping. The top stone in such a gable is named the **apex** or **saddle stone** (Fig. 132). The lowest stone (Fig. 132, *C*) is named the **footstone**; intermediate stones (Fig. 132), which should not be more than seven feet (7′) apart, are known as **kneestones** or **kneelers**. Such kneelers, as well as the footstones, should extend well into the wall, to prevent any danger of sliding of the coping.



Stone Coping on Gable.

Joints in Masonry.—In order to prevent stones from sliding over each other, or to more rigidly connect them together than can be done by mortar or cement, various joints are used. Some of the most important of these will now be considered.

A Rebated Joint, two forms of which are shown in Figs. 133 and 134, is used for copings on gables, flat copings on walls, frequently for landings in staircases, and for many other purposes. The length of the rebate varies according to the class of work, and may be taken as about two and a half inches ($2\frac{1}{2}''$) for copings four inches ($4''$) thick.

Joggle Joint.—This joint involves a great deal of labour, and is therefore very expensive and seldom used. In forming

a joggle joint a projection is left on one stone, and a corresponding sinking made in the other (Fig. 136).

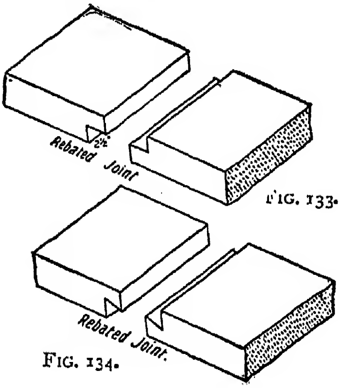
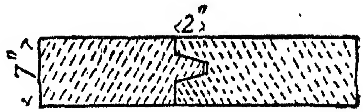


FIG. 133.

FIG. 134.

Rebated Joints.



SECTION through JOGGLE JOINT.

FIG 135.

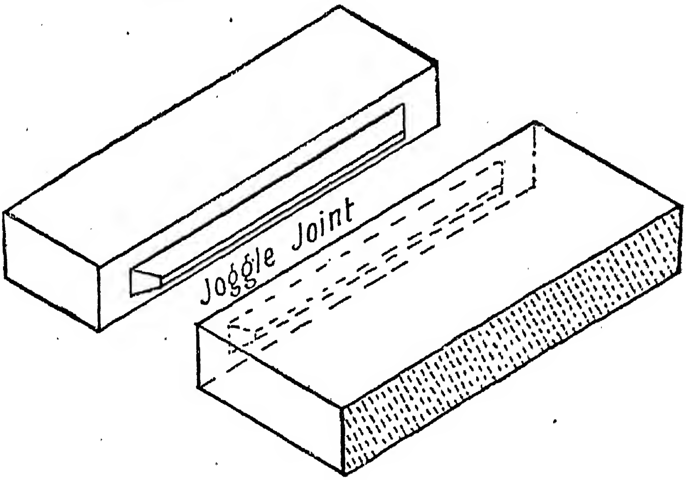


FIG. 136.

A *Dowelled Joint* is the common substitute for a joggle joint; to make it, a hole or mortise is cut into each stone, and loose *dowels* or pins of hard stone, slate, cement, or metal are inserted and secured with cement. Dowelled joints are also extensively used for fixing columns, the mullions and transoms of window-openings, etc. Fig. 137 shows their ap-

plication. A dowel used for columns, or in similar positions, is sometimes called a bed plug (Fig. 138).

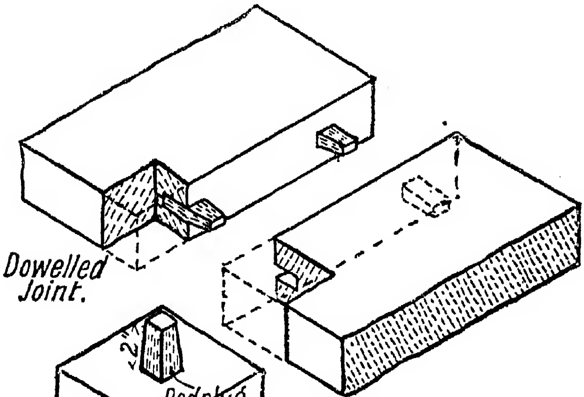


FIG. 137.

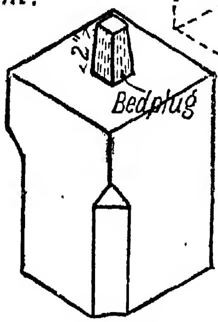


FIG. 138.

A Tabled Joint is a joint (which is, however, seldom used, on account of expense) for holding stones together by a wide projection left on one stone fitting into a corresponding sinking made in the other (Fig. 139).

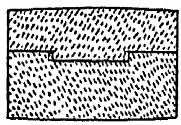


FIG. 139.
Tabled Joint.

Lead Plugs are frequently used to connect such stones as copings, overhanging cornices, blocking-courses, etc. They are made by cutting each end of every stone as shown in Fig. 140 or Fig. 141; the sinkings being opposite each other when the stones are in position. Molten lead is then poured in from the top to fill all the crevices, and the stones are thus prevented from sliding laterally. Similar joints are frequently made by substituting liquid cement for lead.

Metal Cramps run with lead, brimstone, or cement are a frequently-adopted means of securing such stones as copings,

blocking-courses, stone chimney caps, etc. Fig. 143 illustrates

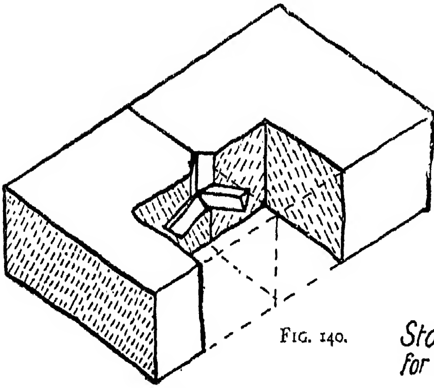


FIG. 140.

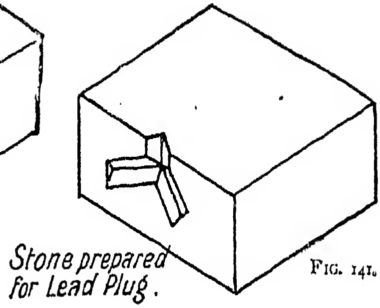


FIG. 141.

their application. The length of such a metal cramp may be anything from seven to twelve inches (7″ to 12″), the ends being turned down about one and a half inches ($1\frac{1}{2}$″). The cramp may be of wrought iron, cast iron,

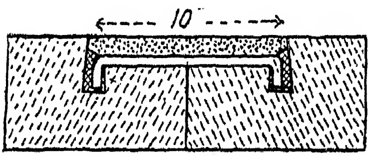


FIG. 142.—Metal Cramp run with Lead or Cement.

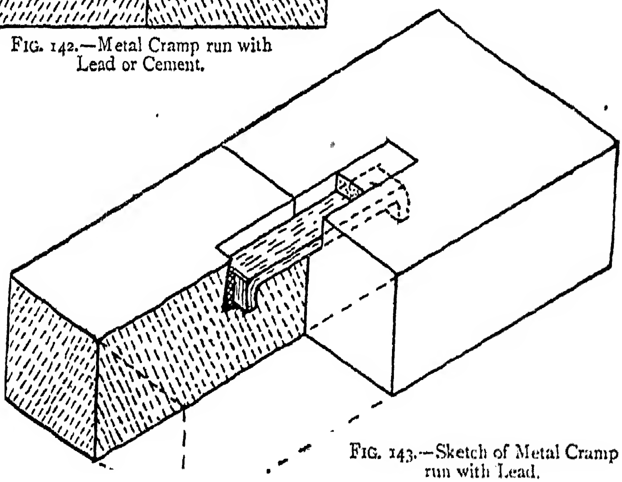


FIG. 143.—Sketch of Metal Cramp run with Lead.

copper, or gun-metal, but of them all the last two are the best.

When wrought- or cast-iron cramps are used, they should either be galvanised, or dipped whilst hot into pitch or gas tar, to prevent rusting. These cramps should always be sunk in such a manner that they lie below the surface of the stone; the cavity is then filled up level with cement. The holes or mortises should be cut dove-tail shape, as shown in Fig. 142; in this way the cramps are better held together.

Corbels.—This name is applied to blocks of stone built into the wall, with one end projecting beyond the surface. These corbels are used for carrying beams, roof trusses, etc. They should always extend into the wall for a distance of at least two-thirds of their length (Fig. 144).

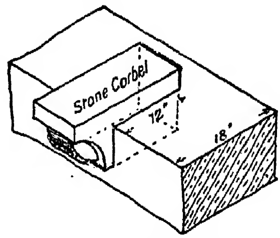


FIG. 144.—Sketch of Corbel.

SUMMARY

Stones used in buildings are obtained from rocks having a distinct plane of division known as the *natural bed.* Each stone should be so laid that the natural bed is at right angles to the pressure. The different kinds of stone walls are classed as—

Rubble (*Random*, *Squared*, or *Coursed*).
Block-in-course.
Ashlar.

The **bonding** of the thickness of these is effected by the use of *through* or *bond stones*. *Larger ashlar blocks*, having their surfaces finished in various ways, are used for *string courses*, *quoin stones*, *window-* and *door-dressings*, *copings*, *cornices*, etc.

Window sills, projecting string courses, copings, cornices, etc., should have their upper surfaces **weathered**, and the under sides **throated.**

Blocks of stone may be connected by *rebated*, *joggle*, or *table joints*, or by means of *dowels*, *molten lead run into sinkings* in the stones, or by *metal cramps.*

QUESTIONS ON STONEWORK

1. Show, to a scale of 1″ to the foot, the elevation of about 5′×3 of each of the following kinds of stone walls :—
   (*a*) Random rubble.
   (*b*) Random rubble built up to courses
   (*c*) Irregular-snecked or squared rubble.

(*d*) Irregular-snecked or squared rubble built up to courses.

(*e*) Coursed rubble.

2. Two stone walls, 16″ and 20″ thick respectively, meet at a right angle. The thinner wall consists of random rubble built up to courses, and the thicker of irregular-snecked rubble. Draw an isometric sketch of about 4′ each way, and 3′ in height, showing the walls, with dressed ashlar quoins, and putting in the necessary bond stones. Draw also a vertical cross section through the thicker wall. Scale, $\frac{3}{4}$″ to the foot.

3. A window-opening, 6′ 0″ high and 3′ 6″ wide, has a stone head 12″ deep, a properly weathered and throated stone sill 12″ wide and 6″ deep, and ashlar quoins each 9″ deep. The surrounding stonework is coursed rubble. Draw an elevation of the same, showing chamfered quoins and head, to a scale of $\frac{3}{4}$″ to the foot.

4. Draw a vertical cross section of the window sill (Question 3), showing a 16″ wall with the sill projecting one and a half inches beyond the face of the wall. Scale, $\frac{1}{8}$ full size.

5. Draw the elevation of the upper part of a doorway 3′ 0″ wide, surmounted by a segmental arch of 9″ rise, showing voussoirs 9″ deep, with a central keystone. The surrounding stonework is block-in-course. Scale, 1″ to the foot.

6. Draw the elevation of the upper part of an opening 5′ wide, finished with a semicircular stone arch. Show the voussoirs stepped on the extrados to fit the courses of the surrounding brickwork, which is in English bond. The quoin stones are of ashlar, alternately 9″ and 14″ long on the face. Scale, $\frac{3}{4}$″ to the foot.

Examination Questions

7. Give a sketch elevation showing a portion of a stone wall built of squared rubble worked up to courses.

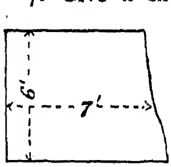


Fig. 145.

*8. Elevation of part of the end of a stone building just above the ground line (Fig. 145).

Draw, to a scale of $\frac{1}{2}$″ to a foot, showing a rusticated stone plinth 22″ high, ashlar quoins, and coursed rubble walling.

*9. Part elevation of a stone wall built in random rubble, and at *A* a lacing course of three courses of bricks laid in Flemish bond (Fig. 146).

Draw, to a scale of $\frac{1}{2}$″ to a foot.

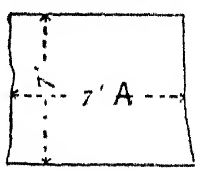


Fig. 146.

*10. Elevation of part of the end of a stone building, in irregular-

coursed or snecked rubble, the quoins being hammer-dressed with drafted margins (Fig. 147).

Draw, to a scale of $\frac{3}{4}''$ to a foot.

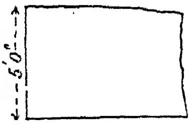


FIG. 147.

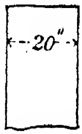


FIG. 148.

*11. Section of a stone wall built of coursed, flat-bedded rubble (Fig. 148).

Draw, to a scale of $\frac{3}{4}''$ to a foot, showing the stones in the wall, including two $\frac{3}{4}$ bond stones, and adding a flush stone coping, weathered at the top.

*12. Section of a coursed rubble dwarf wall (Fig. 149).

Draw, to a scale of $1\frac{1}{2}''$ to a foot, showing the construction, and adding a 6″ stone coping weathered and throated.

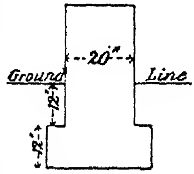


FIG. 149.

*13. Cross-section of a stone to be formed into an ordinary window sill (Fig. 150).


FIG. 150.

Draw, to a scale of $\frac{1}{4}$ full size, the finished section, weathered, throated, and grooved, and fixed in a 14″ brick wall. Two courses of brickwork to be shown below the sill, and two courses in elevation above the stool.

*14. *A* and *B* show two bed-joints in ashlar work (Fig. 151).

Draw *A*, showing the meaning of a hollow joint, with its probable results.

Draw *B*, showing the probable effects of a slack joint at back, packed with spalls.

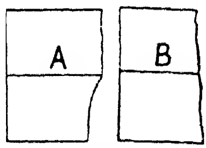


FIG. 151.

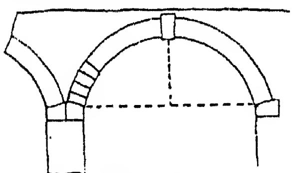


FIG. 152.

*15. Elevation of a stone arch (Fig. 152).

Draw, to twice the scale, and write on it the names of all the different parts of the structure.

*16. Internal elevation of the head of a window-opening in a stone building (Fig. 153).

Draw, to a scale of making any alteration you think necessary.

Give the names of the parts *A* and *B*, and at *C* show rough rubble built up to 20″ courses.

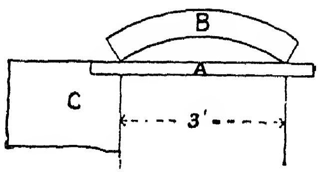


FIG. 153.

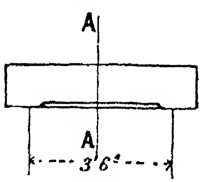


FIG. 154.

*17. Elevation of a window-opening with a stone lintel, the depth of which is equal to four courses of bricks (Fig. 154).

Draw, to a scale of $\frac{3}{4}$ of an inch to a foot, a vertical section through *AA*, the wall being 18″ thick, with a 9″ × 3″ wood lintel, and a discharging arch of two half-brick rings.

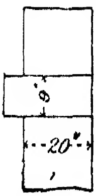


Fig. 155.

*18. Section through part of a stone wall of a dwelling-house, showing a projecting string course (Fig. 155).

Draw, to a scale of $\frac{1}{12}$, showing rubble work built up to courses, and making any alteration you think advisable.

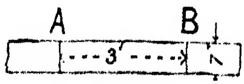


Fig. 156.

*19. Vertical cross-section through the joints of a stone landing (Fig. 156).

Draw, to a scale of $\frac{1}{12}$, showing at *A* a rebated joint, and at *B* a joggled joint.

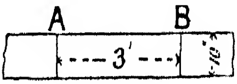


Fig. 157.

*20. Longitudinal section through three coping stones (Fig. 157).

Draw, to a scale of 1½″ to a foot, showing the joint *A* secured by a slate dowel, and *B* by a joggle.

*21. Vertical section of joint between two stones (Fig. 158).

Draw, to a scale of 1½″ to a foot, showing a metal cramp run with lead.

Fig. 158.

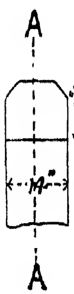


Fig. 159.

*22. Vertical cross-section of a wall with a stone coping (Fig. 159).

Draw, to a scale of 2″ to a foot, a longitudinal section through *A—A*, showing the coping stones cramped together, and the joints of the two top courses of bricks, laid in English bond. State the materials you would prefer to use for the joint.

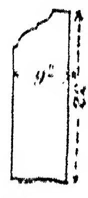


Fig. 16

23. Explain clearly by sketches the meaning of the following terms in connection with masonry joints: Metal cramp run with lead; bed plug; lead plug.

*24. Side view of a stone corbel to carry a girder (Fig. 160).

Draw, to a scale of $\frac{1}{12}$, a section of about ten courses of an 18″ brick wall, showing the bricks and the corbel in position.

CHAPTER IV

GIRDERS AND IRONWORK

Girders.—It frequently happens that openings in buildings occur in places where it would be inconvenient to use arches or stone lintels. As instances of this, openings over shop windows, very wide doorways, etc., may be mentioned. A beam which spans an opening and is supported at each end is known as a *girder* or *bressummer.*

Stress and Strain.—When a weight, or any other force, acts upon a beam, it tends to change the shape or size of the beam. The force is technically called a *stress*, while the change in shape or size produced by the stress is called a *strain.* When a beam, or girder, supported at both ends, is loaded, the upper part is compressed and tends to shorten. The lower part, on the other hand, is in a state of tension, as it tends to stretch. The force acting on the upper part of such a beam is therefore a *compression stress;* that on the lower a *tension stress.*

The existence of these stresses may be made very apparent either by making a saw-cut, or by actually cutting out a wedge-shaped piece from the

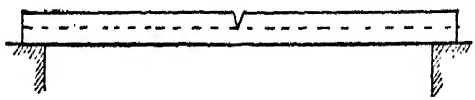


FIG. 161.—Beam cut to illustrate Stresses.

centre of a beam of wood for half its depth, as shown in Fig. 161. On resting the beam on two supports with the cut edge uppermost, and then loading it, it will be seen that the saw-cut closes. This shows that the fibres on the upper side are in a state of compression. If the same piece is now turned over so that the saw-cut is on the lower edge, and again loaded,

the tendency is for the cut to open, thus showing that the fibres on the lower side are in a state of tension.

Beams as Girders.—Wooden beams may be used as girders, and are often put in as "whole timbers." It is better, however, in order to make the girder of uniform strength, to proceed as follows: (1) saw the beam lengthwise down the middle; (2) turn both pieces so that the sawn surfaces are outside; and (3) reverse one of the pieces lengthwise, so that the *butt end* of one half is against the *top end* of the other. The reason for the third step is that timber is stronger at the lower, or butt, end of the tree, than at the top end. (4) The two pieces should then be bolted together at intervals of two feet, the bolts being placed alternately near the upper and lower edges.

Flitched Girders.—A girder of the kind described in the last paragraph is frequently strengthened by inserting a wrought-iron or steel plate, called a **flitch**, between the two pieces, and bolting the whole together. The flitch should be

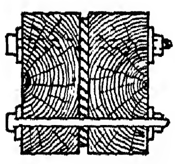


FIG. 162.

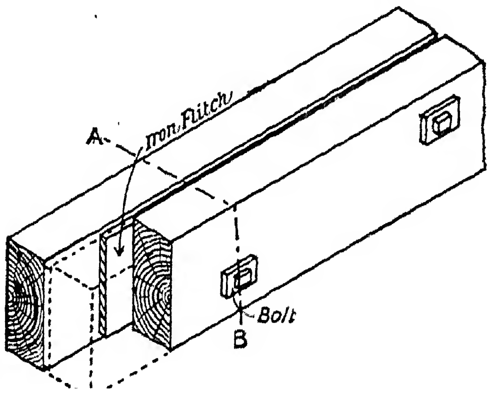


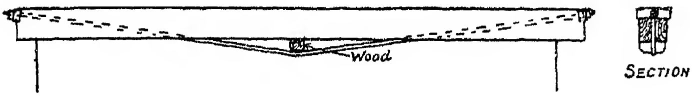
FIG. 163.—Flitched Girder.

at least half an inch narrower than the wooden beams, in case any shrinkage takes place in the latter. Such a combination is named a *flitched girder* (Figs. 162 and 163). To prevent indentations being made by the bolts in the wooden beams, there should be large plate washers under both the head and nut, as shown in Fig. 163.

Trussed Girders.—Another method of strengthening

wooden girders is by means of **trussing**; that is, by using wrought-iron bolts and plates in the manner shown in Figs. 164 and 165. Girders so strengthened are called *trussed*

Fig. 164.



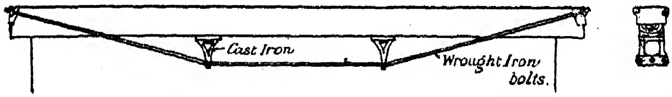


Fig. 165.
Examples of Trussed Girders.

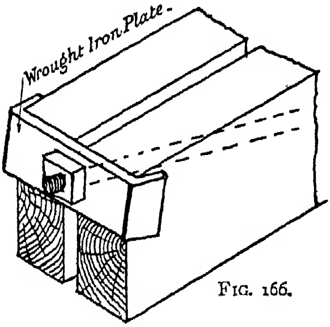


Fig. 166.

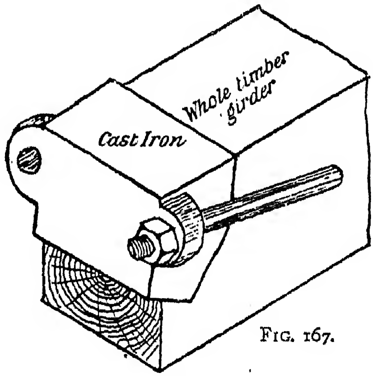


Fig. 167.

Details of the Ends of Trussed Girders.

girders. Figs. 166 and 167 show enlarged details of the ends of such trussed girders.

Iron and Steel Girders.—The construction of iron and steel girders will be apparent from Figs. 168 and 174. The *flanges* are the horizontal members a and b (Fig. 168). The *web* is the upright c connecting the flanges. All internal angles (x, x) where web and flanges meet should be hollowed, and not left square, as they are in Fig. 169.

Cast-iron Girders. — In designing cast-iron girders the following important points have to be borne in mind. Cast iron is approximately six times as strong in compression as in tension.

It crushes at from forty-five to fifty tons per square inch, whereas in tension it will only bear from eight to nine tons per

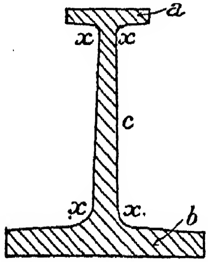


FIG. 168.—Cross-section of Cast-iron Girder.

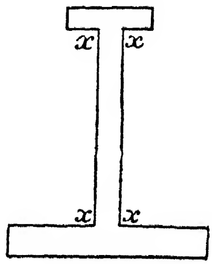


FIG. 169.

square inch. In practice, however, beams are seldom loaded with more than one-sixth of the weight which would produce fracture. For cast-iron beams, therefore, safe working stresses may be taken as about eight tons per square inch in compression, and one and a half tons in tension. Cast iron, like most other solids, contracts on cooling, and if the thickness of different parts of the same casting varies much, there is, owing to the thinner parts cooling first, a danger of fracture.

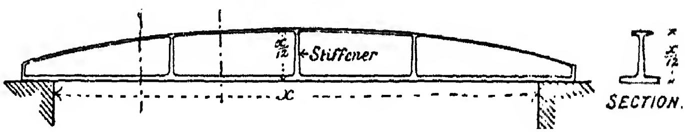


FIG. 170.—Elevation of Cast-iron Girder.

The best shape for cast-iron girders is therefore as shown in section in Fig. 168. The compression flange (*a*) is of about one quarter the sectional area of the tension flange (*b*), while the thickness of the web at each edge is equal to that of the flange to which it is connected. The depth of a cast-iron girder at the centre is usually made about one-twelfth the *span*, that is, one-twelfth the distance between the supports. Cast-iron girders may, without loss of strength, be narrower near the ends than in the middle (Fig. 170). *Stiffeners*, as shown in Fig. 171, should be inserted about every four feet (4′) in length.

Cantilevers are girders fixed at one end only, the other

end projecting from the building. By employing the method of illustrating the stresses in a beam supported at both ends

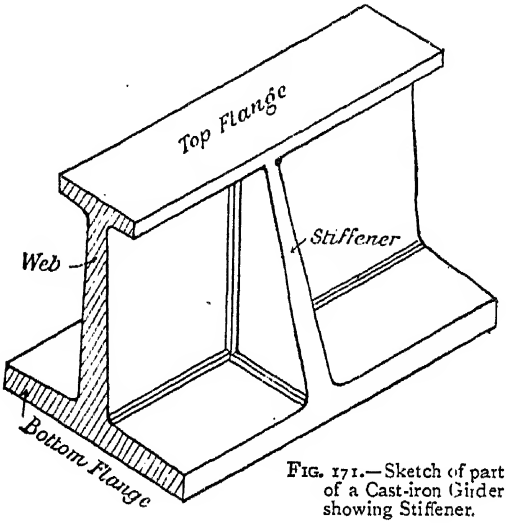


FIG. 171.—Sketch of part of a Cast-iron Girder showing Stiffener.

(p. 49), it will be seen that a cantilever has the upper flange in tension and the lower flange in compression. Such a condition of stress necessitates the larger flange being at the top when cast iron is used. The proportions are the same as

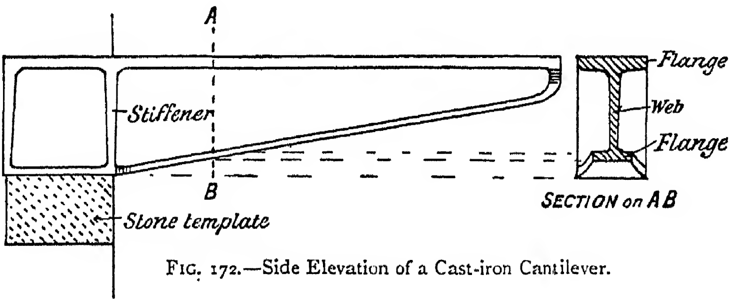


FIG. 172.—Side Elevation of a Cast-iron Cantilever.

in girders. Fig. 172 represents side elevation and cross section, and Fig. 173 is a sketch, of a cast-iron cantilever.

Owing to the improvement in recent years in the manufacture of wrought-iron and steel girders, cast-iron girders and

cantilevers are not so frequently used as was formerly the case.

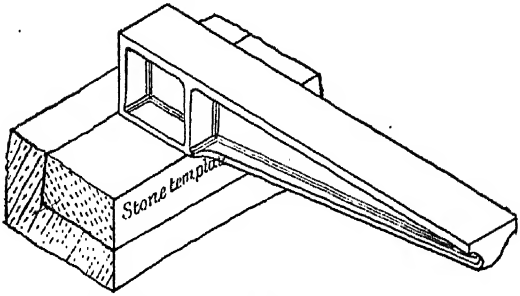
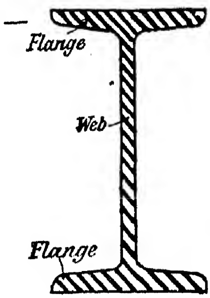


FIG. 173.—Sketch of a Cast-iron Cantilever.

Wrought-iron or **Rolled Girders** contain much less metal than those made of cast iron, and have both flanges of the same size. The greatest tensile stress (*i.e.* the stress in tension) which wrought iron will bear is from twenty to twenty-five tons per square inch; while a safe working stress is five tons per square inch. The greatest compression stress is from seventeen to twenty tons per square inch, with a safe working stress of four tons per square inch. Figs. 174 and 175 show



SECTION.

FIG. 174.

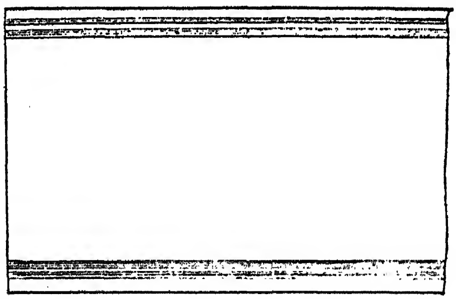


FIG. 175.—Part Elevation of a Rolled Girder.

cross section and part elevation of such a girder. Wrought-iron and steel girders may be obtained up to about eighteen inches (18″) deep. The smaller sizes are named **joists**; they are in great demand for the construction of fireproof floors.

Steel Girders are the same in section as those of wrought iron, but they are a little stronger.

Rivets are small fastenings, made of the best *wrought iron*, used for connecting iron and steel plates together. In fixing a rivet, the *tail* (Fig. 176) is heated and then driven through the plates to be connected together; then the tail and lower part of the *shank* (Fig. 176) of the rivet are hammered, usually to the same shape as the head. As the rivets contract, or shorten, on cooling, they draw the plates together with great force. They are consequently much superior as fastenings to bolts.

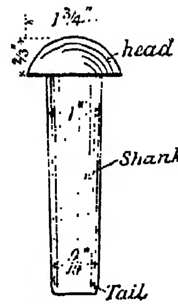


FIG. 176.—Dimensions of a Rivet.

The *heads* of rivets vary in size and shape according to the class of work for which they are used. Each variety, as shown in Figs. 177

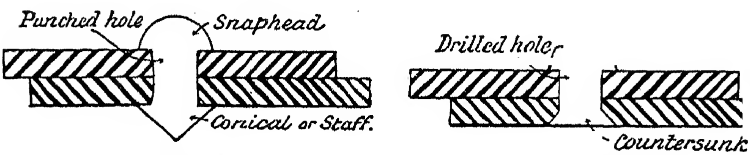


FIG. 177. FIG. 178.

Iron Plates connected by Rivets.

and 178, has a distinctive name. The proportions of *snap-headed* rivets (Fig. 177), are:—

Diameter of head = $1\frac{3}{4}$ times the diameter of shank.
Depth of head = $\frac{2}{3}$ the diameter of shank.
Diameter of rivet = from one and a half to twice the thickness of each plate to be connected by it.

The **pitch** is the distance from the centre of one rivet to the centre of the next, and is from three to five inches (3″ to 5″) in ordinary work. No rivet should be nearer than twice its diameter to the edge of the plate.

Built-up Girders are extensively used, as they are more economical for openings of large span, and for engineering works, than large rolled girders. They consist of plates of wrought iron or steel connected together with angle iron (Fig. 179) and rivets. Other sections, such as L iron, T iron, *channel* iron, *round* iron, *cross* iron, and *flat bar* iron (Figs. 180 to 185), are among the sections used in the construction of the

larger kinds of built-up girders, as well as for iron roof trusses (see Chap. VIII.)

Figs. 186 and 187 show cross section and part elevation of a built-up girder, the flanges and web being connected by angle

FIG. 179.
Angle Iron.

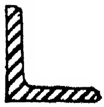


FIG. 180.
L Iron.

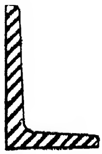


FIG. 181.
T Iron.

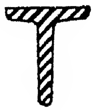


FIG. 182.
Channel Iron.

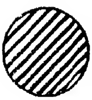
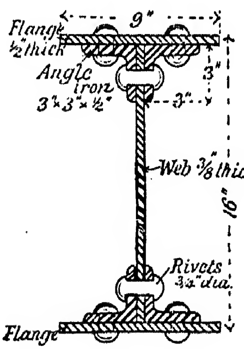


FIG. 183.
Round Iron.

FIG. 184.
Cross Iron.

FIG. 185.
Flat Bar Iron.



CROSS SECTION.

FIG. 186.—Cross section through Fig. 187.

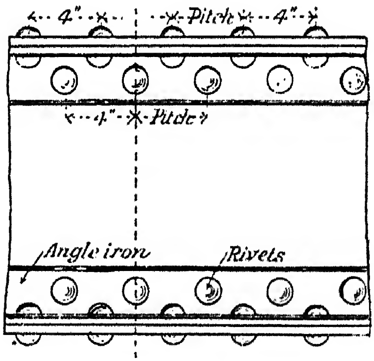


FIG. 187.—Part Elevation of a Built-up Wrought-iron or Steel Girder.

iron and $\frac{3}{4}''$ rivets set to $4''$ pitch. Fig. 188 shows a sketch of a built-up girder of larger size, where the flanges (each formed with two $\frac{1}{2}''$-thick plates) and the web ($\frac{1}{2}''$ thick) are connected together with $3\frac{1}{2}''$ by $3\frac{1}{2}''$ by $\frac{5}{8}''$ angle iron, $\frac{3}{4}''$ rivets set to $4\frac{1}{2}''$ pitch being used: the girder being further strengthened with $3\frac{1}{2}''$ by $3''$ by $\frac{1}{2}''$ L iron stiffeners.

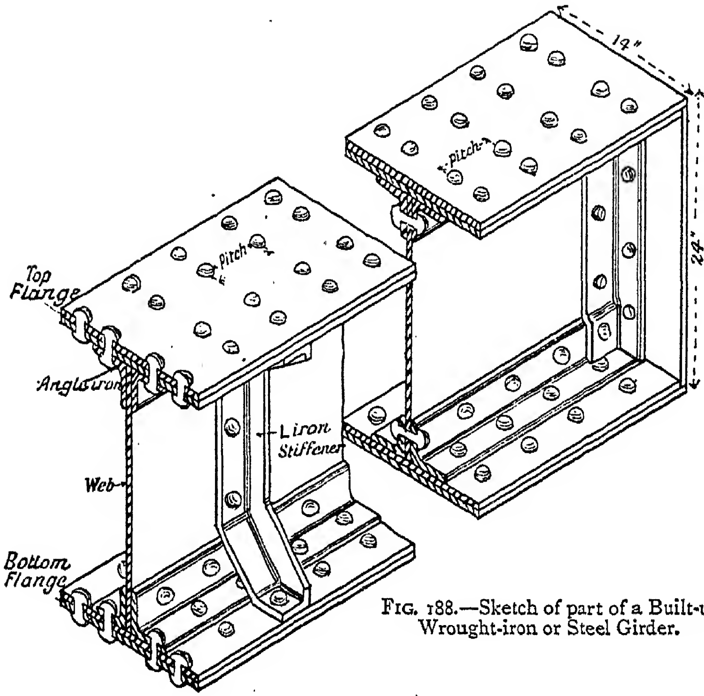
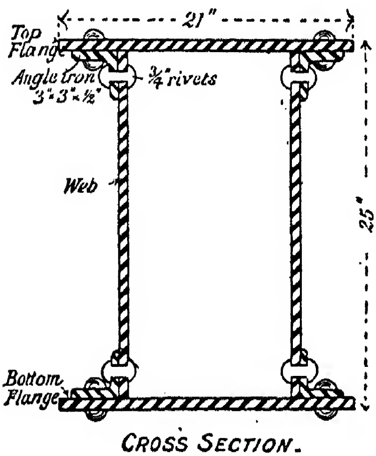


FIG. 188.—Sketch of part of a Built-up Wrought-iron or Steel Girder.



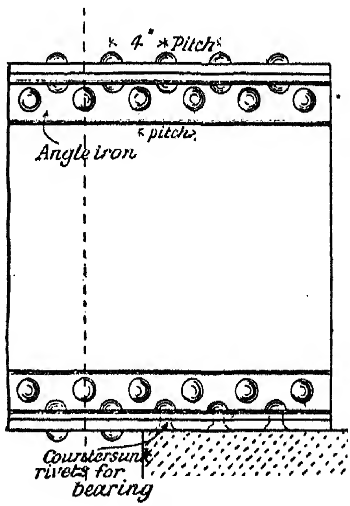


FIG. 189. FIG. 190.—Elevation.

Box Girder.

Figs. 189 and 190 show cross section and part elevation of a girder known as a **box girder**. Girders of this kind are stronger than the I girders, but should only be used when their size is sufficiently large to allow of the inside of the girder being accessible for cleaning and painting.

Riveted Joints.—Wrought-iron and steel plates are fastened together by means of rivets or bolts. Rivet holes

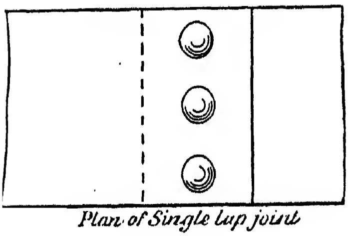


FIG. 191.

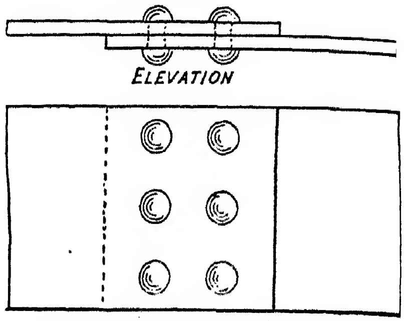


FIG. 192.—Plan and Elevation of Double Riveted Lap Joint.

may be drilled or punched. Rivets, owing to the contraction on cooling, make the best fastenings for permanent work. When the plates overlap each other, as shown in Figs. 191 and 192, the method of connection is named a **lap joint**. When they abut end to end, the joint being made by *cover plates*, either on one or both sides, they are known as **fished or butt joints.**

FIG. 193.—Single Cover-plated Butt Joint.

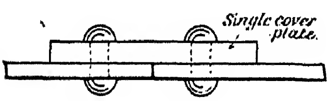


FIG. 194.—Double Cover-plated Butt Joint.

Fished joints are made with either single (Fig. 193) or double (Fig. 194) cover plates. When single cover plates are used, the cover should be a little thicker than the plates connected. If double plates are employed, each plate should be about three-quarters the thickness of the plates to be connected. In some classes of girder work three or more plates may abut against each other and be grouped under one pair of cover plates (Fig. 195). Such a joint is named a **grouped joint.**

The names of joints are further governed by the way in which the rivets are arranged, as *single lap* (Fig. 191), *double*

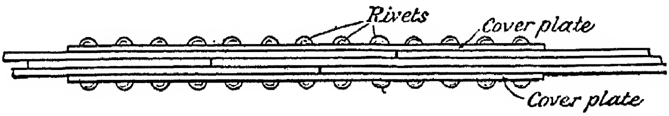


FIG. 195.—Grouped Riveted Joint.

lap (Fig. 192), or, with fished joints, as *single or double rows* on each side of the joint. *Triple* and *quadruple* joints have three and four rows of rivets respectively.

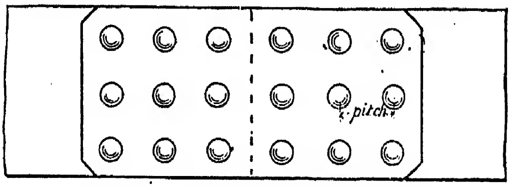


FIG. 196.—Plan of Chain Riveted Joint.

Chain Riveting is the term employed when the rivets are arranged in rows parallel to the edge of the plate (Fig. 196).

Zig-zag is the name used when the rivets are arranged

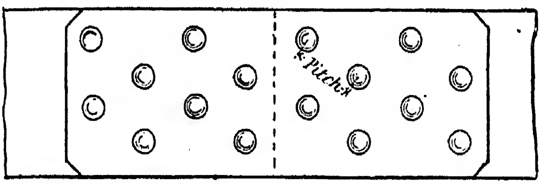


FIG. 197.—Plan of Zig-zag Riveted Joint.

zig-zag or chequer-wise (Fig. 197). This method forms stronger joints than chain riveting, because the holes being placed alternately do not weaken the plate along definite straight lines. Fig. 198 shows the plan of the best form of a lap-joint connection.

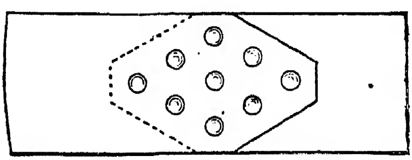


FIG. 198.—Plan of Strongest Form of Lap Riveted Joint.

Summary

A **girder** is a beam of wood, iron, or steel, which is supported at the ends and carries a load. The load is usually carried on the upper side. The upper part of a girder is in a state of compression, and the lower part in a state of tension. These facts (as well as the strength of the material employed) must be taken into account when designing the shape of the section of a girder.

Wooden girders are strengthened by means of *iron flitches* or by *trussing.*

An **iron girder** consists of two flanges connected by a web.

In **cast-iron girders** the sectional area of the tension flange is about four times that of the compression flange.

A **cantilever** is a girder fixed at one end only.

Wrought-iron and **steel girders** have the flanges of the same size. They contain much less metal than cast-iron girders. The heavier kinds of wrought-iron girders are built up from flat plates connected by angle iron and rivets. In connecting iron or steel plates, the joints may be *lapped, fished,* or *grouped.* Fished and grouped joints require *cover plates.*

Rivets are preferable to bolts for forming permanent connections. *Single, double, triple, chain,* and *zig-zag* are terms applied to various arrangements of the rivets in joints.

Questions on Girders and Ironwork

1. Draw the elevation of a cast-iron girder for a 10′ span, the depth of the girder in the middle being 10″, and the flanges 9″ × $1\frac{1}{4}$″ and 3″ × $\frac{7}{8}$″ respectively. Scale, $\frac{1}{2}$″ to one foot. Draw also a cross section through the centre, to a scale of 2″ to the foot.

2. Draw the side elevation and a cross section of a cast-iron cantilever, resting on a stone template and projecting for a distance of 4 feet. Depth of girder at wall end 12″. Flanges, 8″ × $1\frac{1}{2}$″ and 3″ × 1″ respectively. Scale, $\frac{1}{8}$ full size.

3. Draw a cross section and part elevation of a rolled-iron girder, 12″ × 5″, having a $\frac{3}{8}$″ web and $\frac{3}{4}$″ flanges. Scale, $\frac{1}{6}$ full size.

4. Draw, to a scale of 2″ to a foot, a cross section of a wrought-iron girder, 18″ deep by 9″ wide, the flanges, which are plates $\frac{5}{8}$″ thick, being connected to a $\frac{3}{8}$″ web by $3\frac{1}{2}$″ × $3\frac{1}{2}$″ × $\frac{1}{2}$″ angle iron and $\frac{3}{4}$″ rivets. Draw also the elevation of about 2′ 0″ at one end of the girder, showing the rivets set to 4″ pitch.

5. Two iron bars, 10″ wide by $\frac{1}{2}$″ thick, are connected by a riveted lap joint. Draw a plan of the joint, showing three rows of $\frac{3}{4}$″ rivets set to a 4″ pitch. Scale, 3″ to the foot.

6. Two bars, each 12″ × $\frac{1}{2}$″, abut end to end, and are connected by double cover plates, each $\frac{5}{16}$″ thick. Draw the plan of the joint, showing nine $\frac{3}{4}$″ rivets on each side of the joint arranged as chain riveting.

Show an alternate plan of the same joint with zig-zag riveting. Scale, $\frac{1}{6}$ full size.

7. Draw, to a scale of $\frac{1}{3}$ full size, a cross section through the chain-riveted joint (Question 6).

8. Draw a plan of the joint where two $9'' \times \frac{3}{8}''$ plates overlap each other, and are connected with $\frac{5}{8}''$ rivets arranged so as to weaken the plates as little as possible. Scale, $\frac{1}{4}$ full size.

Examination Questions

*9. Cross section of a beam and iron flitch, which are to be formed into a flitch girder (Fig. 199).

Draw the section of the girder, to a scale of $\frac{1}{12}$, showing $\frac{3}{4}''$ bolts by dotted lines.

10. A timber beam, $12'' \times 14''$, is to be strengthened by a $\frac{3}{4}''$ iron flitch.

Give, to a scale of $\frac{1}{6}$, a cross section of the finished girder, showing the annual rings of the timber; also a part elevation sufficient to show the arrangement of the bolts.

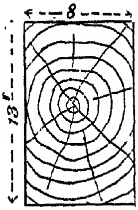


Fig. 199.

*11. Single-line section of a cast-iron girder, which is to be supported at both ends and loaded at the centre (Fig. 200).

Fig. 200.

Draw, to a scale of $2''$ to $1'$, making the top flange $1''$ thick, the bottom flange $1\frac{1}{2}''$, and the web averaging $1\frac{1}{4}''$.

*12. Section of the lower half of a cast-iron girder $14''$ deep (Fig. 201).

Draw, $\frac{1}{4}$ full size, making any alteration you think necessary, and adding the upper part of the section.

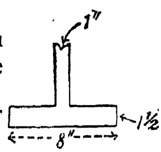


Fig. 201.

*13. Drawing of a stone template to carry the end of a cast-iron girder $10''$ deep, with flanges $1\frac{1}{4}'' \times 8''$ and $\frac{3}{4}'' \times 3''$ (Fig. 202).

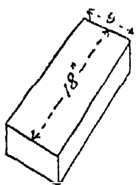


Fig. 202.

Draw the girder, $\frac{1}{2}$ full size, in cross section, showing the template in elevation.

14. A cast-iron cantilever is $10''$ in depth, and its flanges are respectively $4'' \times \frac{3}{4}''$ and $8'' \times 1\frac{1}{4}''$.

Draw its section in position, $\frac{1}{2}$ full size.

*15. Single-line section of a cast-iron girder $10'' \times 4'' \times 15''$ deep (Fig. 203).

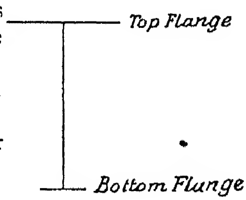


Fig. 203.

Taking the thickness of the top and bottom flanges at $1\frac{1}{2}''$ and $1''$ respectively, draw its section, $\frac{1}{4}$ full size, and state how such a girder ought to be used.

* 16. Elevation of a cast-iron cantilever, 9″ deep, built into a wall (Fig. 204).

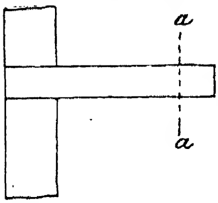


FIG. 204.

Draw, $\frac{1}{3}$ full size, a vertical section through $a-a$, one flange being 6″ × 1″, and the other $2\frac{1}{2}$″ × $\frac{5}{8}$″; also an end elevation of the wall end of the cantilever.

17. Draw, to a scale of $\frac{1}{3}$ full size, a rolled-iron joist 10″ × $4\frac{1}{2}$″, the web being $\frac{3}{8}$″, and the flanges averaging $\frac{3}{4}$″.

* 18. Section of an iron girder (Fig. 205).

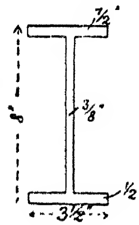


FIG. 205.

Draw, $\frac{1}{2}$ full size, stating against it whether it is intended for a cast- or a wrought-iron girder. Without altering the dimensions, make any improvement in the form you may think advisable.

* 19. Give, to a scale $\frac{1}{4}$ full size, a cross section of a wrought-iron girder built up of the sections indicated by the line diagrams, Fig. 206. Show a part elevation, about 9″ long, with the rivets at a 4″ pitch.

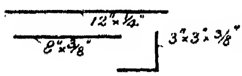


FIG. 206.

CHAPTER

FLOORS

Materials for Floors.—Basement floors, and occasionally ground floors, are constructed of flags, tiles, concrete, or wooden blocks. The upper floors of buildings are generally built either of wood, or of iron or steel girders and concrete. Floors of iron or steel girders and concrete, being fireproof, are extensively used for public buildings, warehouses, workshops, mills, etc.

Flagged Floors are those formed of large thin slabs of hard stone, from two and a half to four inches ($2\frac{1}{2}''$ to $4''$) thick. The upper surfaces of the stone slabs are either naturally smooth (self-faced), or polished, and the edges are worked square. The flags are laid on sand or loose fine gravel, and the joints are made with lime or cement-mortar.

Tiled Floors.—Tiles are much smaller than flags, and are generally of uniform size. When used for floors they should be laid on a bed of concrete and set in cement.

A **Concrete Floor** is one formed by depositing over the surface a layer of rough Portland cement-concrete (Chap. XIV.) from four to six inches ($4''$ to $6''$) thick, and then covering this with a thin layer of fine cement-mortar (Chap. XIV.) and trowelling the surface smooth.

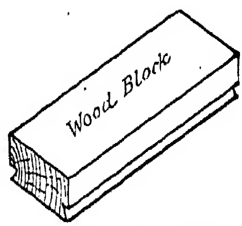


FIG. 207.—As used in Wooden Block Floor.

A **Wooden Block Floor** is laid on a bed of concrete. The blocks are from six to twelve inches ($6''$ to $12''$) long, three inches ($3''$) wide, and about one and a half inches ($1\frac{1}{2}''$) thick, and have the under sides cut as shown in Fig. 207. They are secured together and

in position by being embedded in a mixture of pitch or tar used whilst hot.

Whatever class of floor be used, it is always essential that the ground inside all buildings should be covered with a layer of concrete from four to six inches (4″ to 6″) thick. This precaution prevents the damp from rising out of the ground.

Wooden Floors are named **single**, **double**, or **framed**, according to the way in which the various timbers or **scantlings** are arranged.

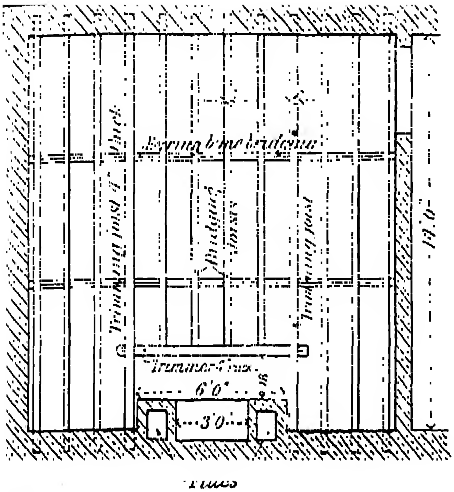
Joists are *planks* or **battens** of timber placed on edge and laid from twelve to fifteen inches (12″ to 15″) apart. The floor boards rest on the top of the joists. In upper floors the joists carry on their under sides either the lath-and-plaster ceiling, or the ceiling joists to which the laths and plaster are fixed.

Single Floors are those the joists of which stretch from wall to wall. Single floors are the most economical and best where the span does not exceed sixteen feet (16′). Figs. 208 and 209 show plan and section of a single floor. When single floors are used as ground floors the joists are supported at intervals of five or six feet (5′ or 6′) by *sleeper walls* (Fig. 210). In such cases the depth of the joist may be materially reduced.

Wall-plates.—The ends of all floor joists should rest on *wall-plates*, which are lengths of timber about four and a half inches ($4\frac{1}{2}$″) wide, and three inches (3″) thick (Figs. 211, 212, and 213). Wall-plates should also be used at any intermediate points of support, such as those of sleeper walls.

The ends of joists, in basement floors, should *not* be built into the wall, but should rest on **offsets**, which are formed by having the walls thicker below the ground floor, as shown in Fig. 68. This precaution is adopted to meet the difficulty of the rotting of the joist. These offsets are frequently obtained in buildings several stories high by diminishing the thickness of the wall at the floor levels (Fig. 211). Where offsets are inconvenient, an alternative method of carrying joists is by building projecting courses of bricks, as shown in Fig. 212. These projecting courses are named *over-sailing* courses, and the arrangement is known as **corbelling**. The projection required, about four and a half inches ($4\frac{1}{2}$″), is obtained in

FIG. 208.—Plan of a Single Floor.



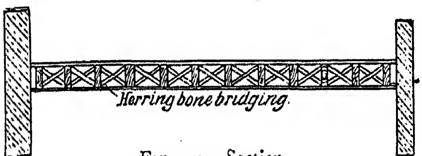


FIG. 209.—Section.

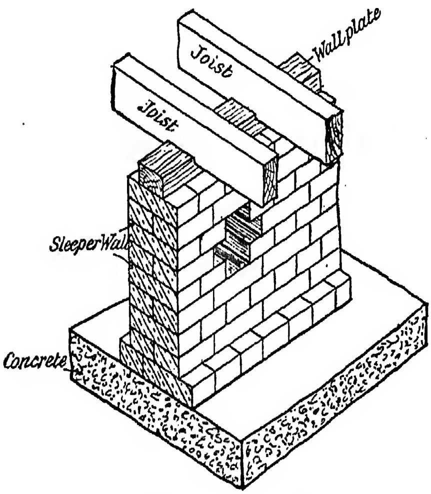


FIG. 210.—Sketch of part of a Brick Sleeper-wall

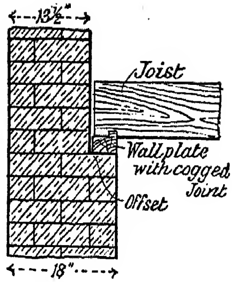


FIG. 211.—Section through Wooden Floor carried on Offset.

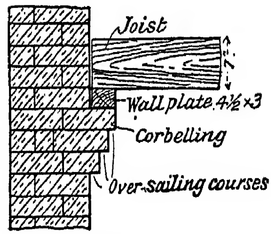


FIG. 212.—Section through Wooden Floor carried on Brick Corbelling.

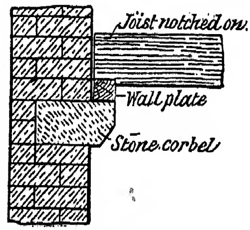


FIG. 213.—Section through Wooden Floor carried on Stone Corbels.

three or more courses, and supports the wall plate. The same object can be attained by using stone corbels (Fig. 213).

It is especially advisable to adopt one of these methods of carrying the upper wooden floors in large warehouses, workshops, etc.; otherwise, in case of fire, the middle part of the floor might be first destroyed, and the remainder would then act as a cantilever, when there would be considerable danger of the walls being overthrown.

How the Joists should rest.—The joists may rest on the wall plates, as in Fig. 212; be *notched on*, as in Fig. 213; or they may be *cogged*, as shown in Fig. 211.

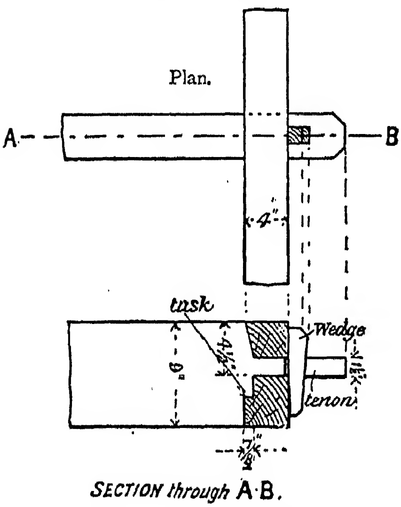


FIG. 214.—Tusk-tenon Joint.

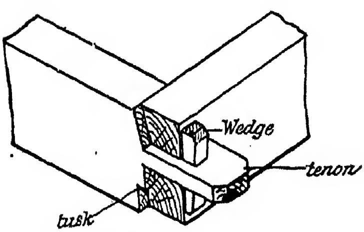


FIG. 215.—Sketch of Tusk-tenon Joint.

When joists are built into the wall, an air-space of at least half an inch should be left along the sides and above each joist, to prevent decay. As a substitute for a wall plate, when joists are built into the wall, an iron bar two and a half inches ($2\frac{1}{2}''$) wide and half an inch ($\frac{1}{2}''$) thick may be laid in the wall for the ends of the joists to rest upon. This bar is not so liable to be destroyed, by damp or other agency, as a wooden wall plate.

Trimming.—No timber should be placed nearer than six inches (6") to a chimney flue. This necessitates an arrangement of the floor joists named *trimming*. In trimming, the joists (called bridging joists) which would abut against the flue are supported by a cross piece called a **trimmer**. The ends of the trimmer are carried by two thicker joists called **trimming joists**. Reference to Fig. 208 will make this clear.

Openings for staircases, well-holes, etc., are also provided with a system of trimming.

Tusk-tenon Joint.—The form of joint mostly used in trimming is known as a *tusk-tenon joint.* Fig. 214 shows plan and section, and Fig. 215 is a sketch of this joint. As this joint is specially constructed to prevent unnecessary weakening of the timbers, its proportions should be carefully noticed. The thickness of the tenon (Figs. 214 and 215) is one-sixth the depth of the joist, and the tenon is so fixed that it has its lower surface in the centre of the depth. The *tusk* (Figs. 214 and 215) extends into the joist for a distance equal to one-fifth the thickness of the joist. Fig. 214 gives dimensions of this joint which conform to the above proportions. The projection of the tenon beyond the surface of the joist, as well as the wedge, are omitted where they would be in the way, as in the joint between the trimmer and *bridging* joists (Fig. 216).

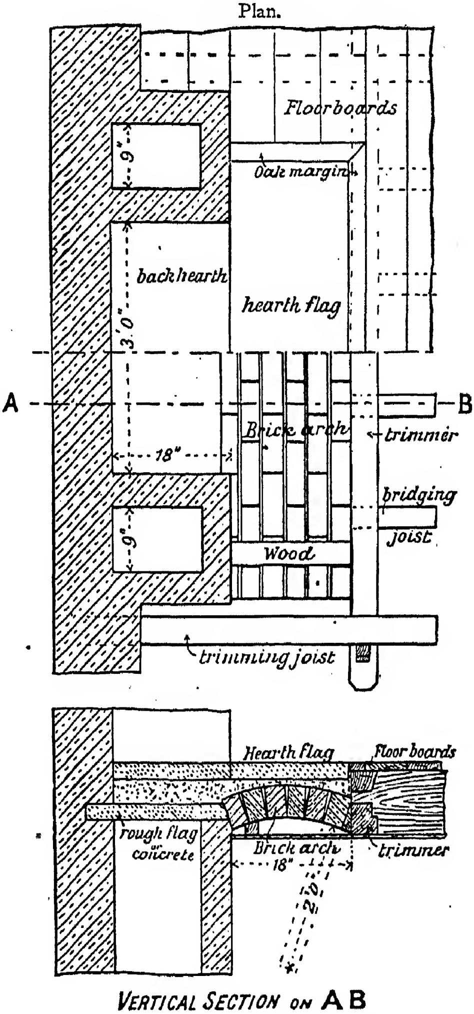


FIG. 216.—Brick Trimmer Arch, Hearth Flag, etc.

Hearth-flag and Trimmer Arches.—When a fireplace

occurs in an upper room, it is necessary to have a hearthflag from three feet six inches to five feet (3′ 6″ to 5′) long, and projecting at least eighteen inches (18″) from the front of the fireplace. The flag is best supported by a brick arch known as a *trimmer arch*, which springs from the brick-work on one side, and from the trimmer on the other. Fig. 216 shows the plan and a vertical section of a fireplace. The upper half of the plan

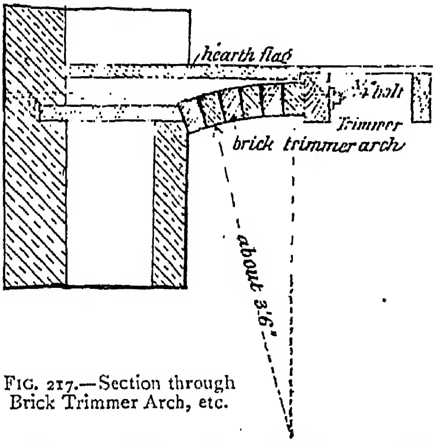


FIG. 217.—Section through Brick Trimmer Arch, etc.

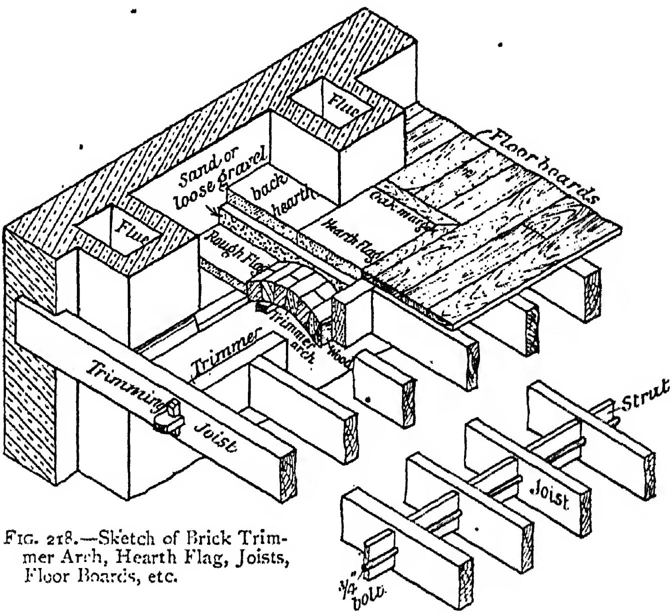


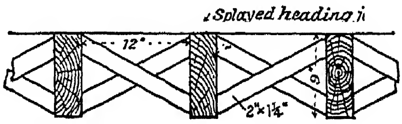
FIG. 218.—Sketch of Brick Trimmer Arch, Hearth Flag, Joists, Floor Boards, etc.

shows the hearth-flag, floorboards, etc., in position; in the lower part of the plan the brick trimmer arch and joists

are shown. Such an arch is named a *coach-headed* trimmer arch. Fig. 218 is a sketch of the same fireplace, showing the construction still more clearly. As an alternative, the trimmer arch may abut square on the trimmer, as shown in section in Fig. 217. This is necessary when the joists are not more than seven inches (7″) deep. Tiles of various kinds are often substituted for a hearthflag.

Bridging and Strutting.—Single floors are strengthened by placing rows of *herring-bone bridging* or *strutting* at right angles to the direction of the joists, and at distances of four or five feet (4′ or 5′) apart. This strutting is formed by pieces of timber, about two inches by one and a half inches (2″ × 1½″) crossing each other, and nailed to the joists in the manner shown in Figs. 209 and 219. An alternative plan is that known as *solid strutting*. Solid strutting consists of tightly fixing rows of short boards on edge between the joists. Such boards are one inch (1″) narrower than the depth of the joists, and from one to one and a half inches (1″ to 1½″) thick. When solid strutting is adopted the floor may be further strengthened—

Fig. 219.—Section through three Joists, showing Herring-bone Strutting.



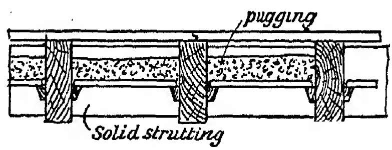


Fig. 220.—Section showing Sound-boarding and Pugging.

(*a*) By passing a three-quarter inch bolt through the centre of the depth of the joists, close against the strutting, thus binding the whole together (Fig. 218).

(*b*) By nailing hoop iron (one and a half to two inches (1½″ to 2″) wide, and one-sixteenth of an inch ($\frac{1}{16}$″) thick) along the top and bottom edges of the joists where the strutting is fixed, and then tightening up the struts by means of wedges.

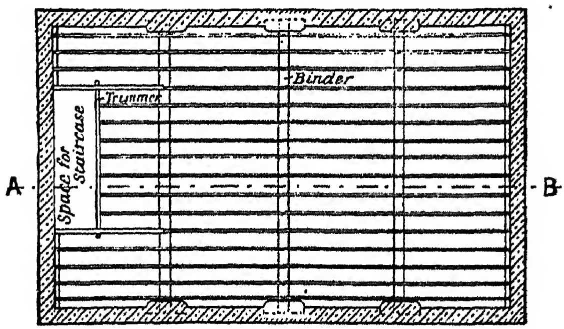
Sound-boarding and Pugging.—This name is given to a device adopted to prevent the passage of sound from a room to the one below. It consists of laying a floor of rough short boards about half-way down the depth of the joists, and resting on fillets, shaped as in Fig. 221, and

Fig. 221.

nailed on both sides of each joist. These boards carry rough mortar, often mixed with ashes, sawdust, or silicate cotton, laid to a depth of about three inches (3″). The rough mortar, etc., is named *pugging*. An alternative to pugging is to make every fourth joist about two inches (2″) deeper than the others, and to secure ceiling joists to the under side of the deeper joists. The lath-and-plaster ceiling is fixed to the lower side of the ceiling joists.

Double Floors.—Double floors have beams or **binders** placed from six to ten feet (6′ to 10′) apart. On these rest the bridging joists which carry the floor boards. In double and framed floors the weight of the whole of the floor is concentrated on a few points. This may be an advantage when there are many window openings, or where the wall can be strengthened

FIG. 222.—Plan of a Double Floor.



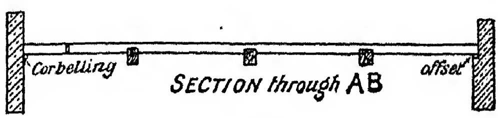


FIG. 223.

by piers; but, as the floor helps to bind the walls together, a single floor does this more effectively, as the joists distribute the weight more equally on the walls. Again, double floors take up a greater depth than single floors, and thus, by requiring higher walls for the same height of rooms, increase the cost of buildings. Double floors are, however, most suitable for rooms from sixteen to twenty-four feet (16′ to 24′)

wide. Figs. 222 and 223 show plan and section of a double floor.

In order to reduce the depth of the double floor without materially affecting its strength, the joists are often **cogged** on to the binders, as shown in Figs. 224 and 225.

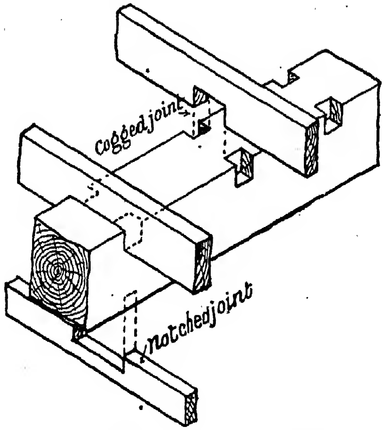


FIG. 224.—Sketch showing Cogged and Notched Joints.

Ceiling Joists.—When ceiling joists are used in double or framed floors they may—

(*a*). Be notched to the under side of the binder, as in Fig. 224.

(*b*) Be made to fit between the binders, and rest on strips of wood named *fillets* (Fig. 225).

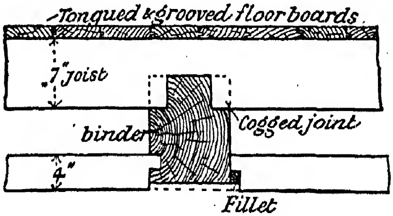


FIG. 225.

(*c*) Have short tenons formed on the ends of the ceiling joists with corresponding holes or mortises in the binders. The binders are cut or "chased" out to enable one end of the ceiling joists to be put into position after the binders are fixed (Fig. 225). This latter method is named *chase mortising*, and is seldom adopted.

Framed Floors.—Framed floors are used in large warehouses, workshops, mills, etc. They consist of girders, binders, bridging joists, floor boards, and, when a plaster ceiling is required, ceiling joists. Fig. 226 shows the plan of a framed floor with part of its surface covered with floor boards. Many of the bridging joists are omitted for the sake of clearness in this figure. The trimming around the hearth in the case of such a framed floor is somewhat different from that described in the earlier part of the chapter. As will be seen by referring to the figure, two bolts are employed to

strengthen the joist against which the trimmer arch abuts.

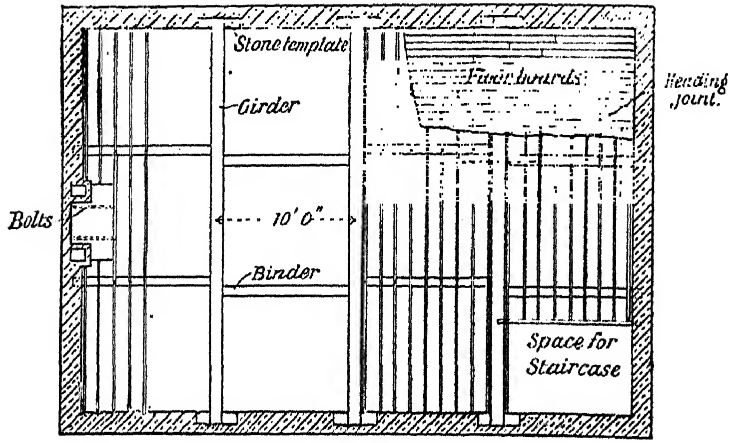


Fig. 226.—Plan of a Framed Floor.

Fig. 217 shows a section through a trimmer arch applicable to the fireplace in the framed floor of Fig. 226. When this class of floor is framed entirely with wooden beams, the binders are often tusk-tenoned into the girders, as shown in Figs. 227 and

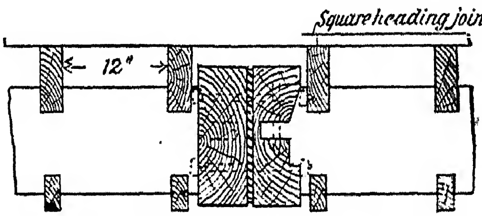


Fig. 227.—Section through a Wooden Girder showing Tusk-tenon Joint between Binder and Girder.

228. Such a joint, however, weakens the girder considerably, and a much better connection can be made by resting the binder in a cast-iron shoe or *stirrup*, having a small projection behind, which is let into the beam. The stirrup itself is secured to the girder with coach screws. The form of joint used to connect the binder and bridging joists is the cogged joint (Fig. 224). It remains to be mentioned that flitched and trussed girders are often used in framed floors.

Stone Templates.—The ends of all beams used in floor

and roof construction should rest on *stone templates* or *pad-stones*, which are from two to three feet (2′ to 3′) long, nine

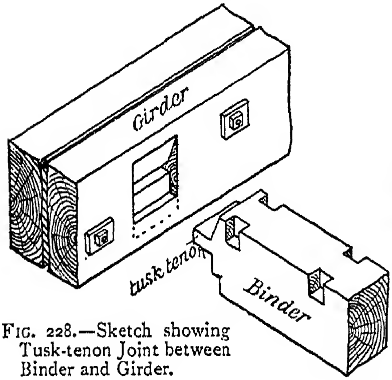


FIG. 228.—Sketch showing Tusk-tenon Joint between Binder and Girder.

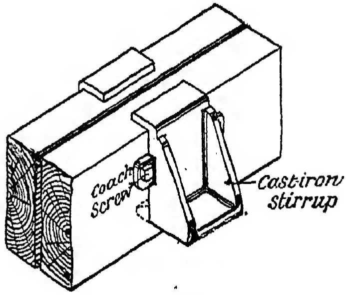


FIG. 229.—Cast-iron Stirrup to carry Binder.

to twelve inches (9″ to 12″) wide, and four to six inches (4″ to 6″) thick. The openings into which beams requiring stone templates rest should be at least one and a half inches ($1\frac{1}{2}$″) wider than the thickness of the beam, to allow for an air-space on each side of it. An air-space, which may be closed by a brick arch (Fig. 230), or by a stone lintel, should also be provided on the top of the beam.

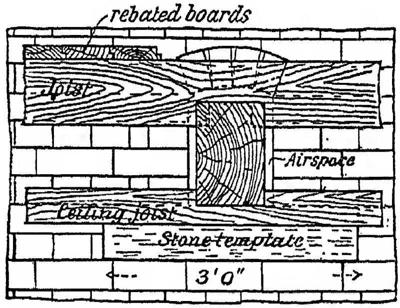


FIG. 230.—Vertical Section through Binder showing Air-space or Pocket in Elevation.

The Use of Wrought-iron and Steel Girders in Floor Construction.—Wrought-iron and steel girders have in recent years almost entirely taken the place of heavy wooden beams for floor construction. The wooden joists may be supported on the top flange of the girder, as is shown in Fig. 231; or on pieces of timber resting on the bottom flange of the girder, and bolted through its web, as is easily understood by referring to Fig. 232. Or, again, if the joists are deep enough, they may themselves rest on the lower flange of the iron girder itself. The unsightly appearance of iron girders when con-

structed as in Fig. 231 may be entirely avoided by encasing them in wood or plaster.

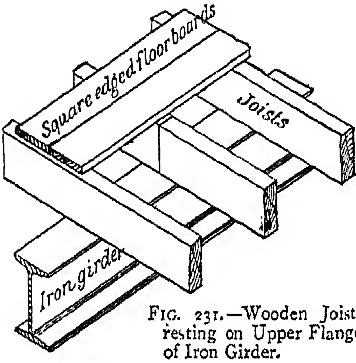


FIG. 231.—Wooden Joists resting on Upper Flange of Iron Girder.

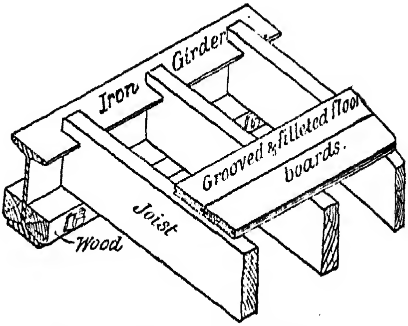


FIG. 232.—Wooden Joists resting on Iron Girder.

Encasing of Girders.—Plain wooden casings formed out of three-quarter inch ($\frac{3}{4}''$) tongued, grooved, and beaded boards, secured to rough packing pieces nailed to every second joist, are shown at *A* in Fig. 233. Framed and panelled linings are sometimes used as an alternative means of encasing girders, and their construction will be understood by examining Fig. 233, *B*. When plaster is used to encase a girder, the rough packing pieces which are required are nailed against every joist, and the laths which carry the plaster are nailed to them.

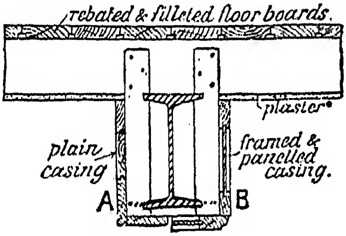


FIG. 233.—Alternative Methods of Encasing Iron Girders.

Floor Board Joints.—The edges of floorboards, or floor **battens**, as they are also called, are prepared in many different ways. The joints most commonly used are the *square-edged* (Fig. 234) and the *tongued and grooved* (Fig. 235). Figs. 236 to 240 show other less frequently employed joints, with their distinctive names appended. Fig. 240 shows a form of joint used in the construction of superior floors. In this each board is laid and nailed separately to the joist. The object of using this form of joint is to obtain a finished floor with a surface free from unsightly nail-holes.

Dimensions of Floorboards.—The width of floor-boards in general use varies from four to seven inches (4″ to 7″), and the thickness from seven-eighths to one and a half inches ($\frac{7}{8}$″ to $1\frac{1}{2}$″). It is not uncommon, in warehouses or where heavy traffic exists, to construct the floors of boards having a thickness of from two and a half to three inches

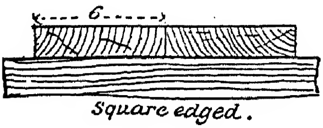


FIG. 234.

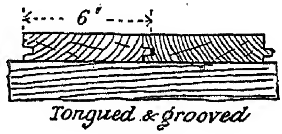


FIG. 235.

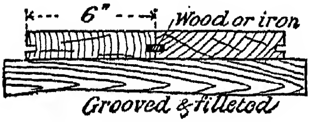


FIG. 236.

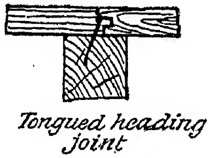


FIG. 237.

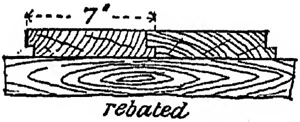


FIG. 238.

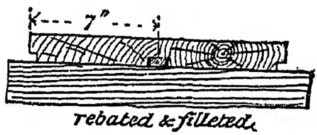


FIG. 239.

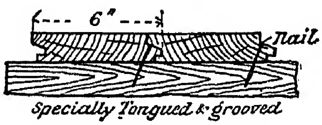


FIG. 240.

Floor Board Joints.

Heading Joints.—Heading joints are those formed by joining the ends of boards together. A heading joint must always be over a joist. In construction they are very similar to the edge joints already described. The forms of heading joints mostly used are the *square heading* (Fig. 227) and *splayed heading* (Fig. 219). For superior floors, however, the *tongued and grooved* joint is nearly always employed. A tongued and grooved heading joint is shown in Fig. 237.

Floors are occasionally laid with two thicknesses of boards. In these cases the lower thickness is constructed of rough boards about three-quarters of an inch ($\frac{3}{4}''$) thick. The top layer may be very conveniently left until all subsequent plastering is finished; there is then no liability of the upper layer being affected by dampness.

Fireproof Floors.—Fireproof floors may be constructed with girders of wrought iron or steel, on which rest smaller steel joists placed from eighteen inches to two feet ($18''$ to $2'$) apart. The space between these joists is then filled with cement-concrete to a depth of six to eight inches ($6''$ to $8''$), a temporary sheeting of planks being fixed on the under side to carry the concrete until it sets. When a wooden floor is required on the upper surface, wooden blocks, as already described, may with advantage be used. Another plan is to employ wooden joists about three inches by two and a half inches ($3'' \times 2\frac{1}{2}''$) cut dovetail shape (Fig. 241). Such joists are embedded whilst the

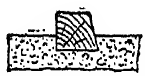


FIG. 241.

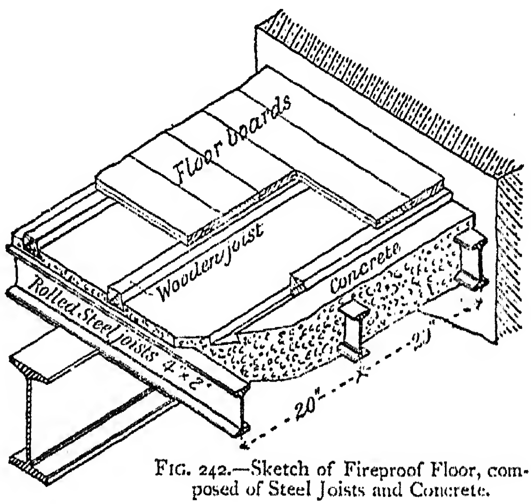


FIG. 242.—Sketch of Fireproof Floor, composed of Steel Joists and Concrete.

concrete is being laid (Fig. 242), and the floor boards are afterwards nailed to these in the usual manner.

SUMMARY

Wooden floors are known as *single*, *double*, or *framed*, according to the arrangement of the timbers composing them. They consist of *joists*, *binders*, *girders*, *floor boards*, and *ceiling joists*.

Joists ought, wherever possible, to rest upon *offsets* or *corbels* in preference to being built in the wall. When a *joist*, *binder*, or *girder* is built into a wall, an air-space should be left around it to prevent decay of the joist. All binders and girders should rest on *stone templates*. Around staircase openings and fireplaces the joists are *trimmed;* the joint used in trimming is the *tusk-tenon* joint.

Floors are strengthened by *herring-bone bridging* or by *solid strutting*. Joists and binders are connected by a *cogged joint*. Binders and girders may be connected either by a *tusk-tenon joint*, or by means of an *iron stirrup*.

Iron and steel girders are much used in floor construction. *Floor boards* may have their edges *square*, *tongued and grooved*, *grooved and filleted*, *rebated*, *rebated and filleted*, or *tongued and grooved* for *secret nailing*. The ends of floor boards meeting on a joist form a *heading joint*.

Fireproof floors are often constructed with *cement-concrete* carried by iron or steel girders.

QUESTIONS ON FLOORS

*1. The sketch shows the figured plan of a room with a fireplace. Draw, to a scale of $\frac{3}{8}''$ to the foot, a plan and vertical section through *AB*, showing the arrangement of the joists; $9'' \times 4''$ trimming joists and trimmer, and $9'' \times 3''$ bridging joists placed 12″ apart.

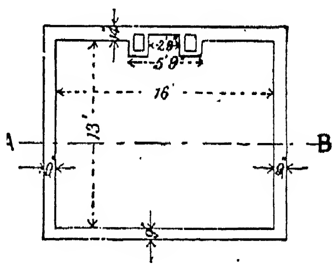


FIG. 243.

2. Draw the following details of the floor in Question 1:—

(*a*) A cross section through four joists showing $2'' \times 1\frac{1}{4}''$ herring-bone strutting. Scale, $1\frac{1}{2}''$ to the foot.

(*b*) Plan and section of the tusk-tenon joint between the trimmer and the trimming joist. Scale, $\frac{1}{6}$ full size.

(*c*) Plan and cross section of a coach-headed trimmer arch bearing a $2\frac{1}{2}''$ hearth flag, surrounding floor boards being $5'' \times 1\frac{1}{4}''$ tongued and grooved. Scale, 1″ to the foot.

3. Draw, to a scale of $\frac{1}{4}''$ to the foot, the plan of a double floor for a room $17' \times 20'$, having binders $12'' \times 8''$, and floor joists $6'' \times 2\frac{1}{2}''$

16. Give a cross section, to a scale of $\frac{3}{4}''$ to a foot, through two binders of a double floor, from the following details :—

Fir binders, $10'' \times 12''$, at $9'$ centres.
Joists, $7'' \times 2''$.
Ceiling joists, $4'' \times 2''$.

The total depth of the floor to be $16''$, the ceiling being level throughout.

* 17. *A* and *B* are sections through a wooden floor girder and a bridging joist (Fig. 252).

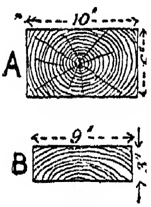


FIG. 252.

Draw, to a scale of $\frac{1}{8}$, two cross sections of the girder, showing the joist notched to it in the one case, and cogged to it in the other.

The cogged joint to be marked *C*, and the notched joint *N*.

18. Give, to a scale of $\frac{3}{4}''$ to a foot, sections, at right angles to the direction of the floor boards, showing the difference between a double and a framed floor.

The double floor to be finished with $1\frac{1}{2}''$ rebated boards, and the framed floor with $1\frac{1}{2}''$ battens, rebated and filleted.

Their names to be written against the different members.

19. Give, to a scale of $\frac{3}{4}''$ to a foot, sections across a few floor boards, showing the construction of—

A single floor with $1\frac{1}{2}''$ boards, rebated and filleted.
A double floor with $1\frac{1}{2}''$ boards, grooved and tongued.

20. Give, to a scale of $\frac{1}{10}$, a cross section through two girders of a framed floor constructed as follows :—

Girders, $12'' \times 10''$, and $8'$ apart.
Binders, $8'' \times 5\frac{1}{2}''$.
Bridging joists, $6'' \times 2''$.
Ceiling joists, $3'' \times 2''$.

21. Give a cross section, to a scale of $\frac{1}{3}$ full size, through four $1\frac{1}{4}''$ floor battens, showing the following joints—rebated; rebated and filleted; ploughed and tongued. Put its name against each.

22. Give sketches, quarter full size, showing—

(*a*) Three $1\frac{1}{2}''$ floor *boards* with rebated joints, face nailed to a $9''$ joist.

(*b*) Three $1\frac{1}{2}''$ floor *battens* with dowelled joints, secret nailed to a $9''$ joist.

23. Draw a section, to a scale of $1\frac{1}{2}''$ to a foot, through a double floor consisting of rolled-iron girders $10'' \times 4\frac{1}{2}''$, common joists $2\frac{1}{2}'' \times 8''$, and $1\frac{1}{2}''$ battens ploughed and tongued with hoop iron. The section to show six battens.

* 24. Plan of part of an ordinary wooden floor (Fig. 253).

Draw, to a scale of $1\frac{1}{2}''$ to a foot, a section through *A—A*, showing $1\frac{1}{2}''$ battens, rebated and filleted; also a section through *B—B*, showing a bevelled heading-joint, and three joists, $11'' \times 2''$, spaced $12''$ apart.

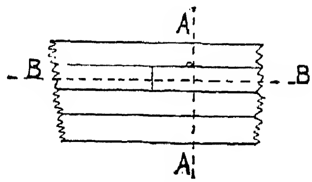


FIG. 253.

CHAPTER VI

PARTITIONS

Partitions.—It is often inconvenient to have the upper rooms of a building of the same size and shape as the lower rooms. In such cases the walls which divide the lower rooms cannot be carried upwards to form the divisions of the higher rooms. For various other reasons it may be undesirable to continue brick division walls to the upper stories. The rooms of the upper stories may, however, be separated by **partitions** of wood and plaster.

A frequently adopted means of forming these partitions is to fix upright pieces of wood named **studs** in the same vertical plane at distances of from twelve to fifteen inches ($12''$ to $15''$) apart. The wooden laths which carry the plaster are nailed to both sides of these studs. As a further means of stiffening the studs, short horizontal pieces of wood, three inches by one and a half inches ($3'' \times 1\frac{1}{2}''$), called *nogging pieces*, are fitted and nailed between them in rows, at distances of about four feet ($4'$) in height. This method of arranging studs has, however, the disadvantage of throwing the whole of the weight of the partition on the floor on which it rests; and any settlement or "sagging" of the floor naturally strains the partition and tends to crack the plaster.

As the studs and other pieces of timber used in framing are of section known as *quartering*, two inches square to six inches square ($2'' \times 2''$ to $6'' \times 6''$), such partitions are known as *quartered partitions*. The usual section of studs used in partitions is two inches ($2''$) wide by the thickness of the partition, it being necessary to have all the members of the same partition of the same thickness to enable both sides to be plastered evenly.

Framed and Trussed Partitions.—A better method than the above is to support the partition by a framework, or **truss**, so arranged that the whole weight of the partition is directly transmitted to the walls. Fig. 254 is a line diagram of a *framed partition* without any doorway. Each piece of timber, or member, is shown by a single line. Fig. 255 shows the

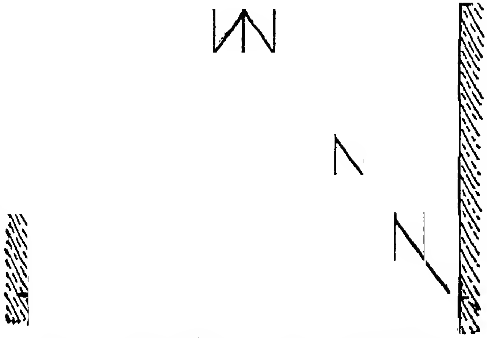
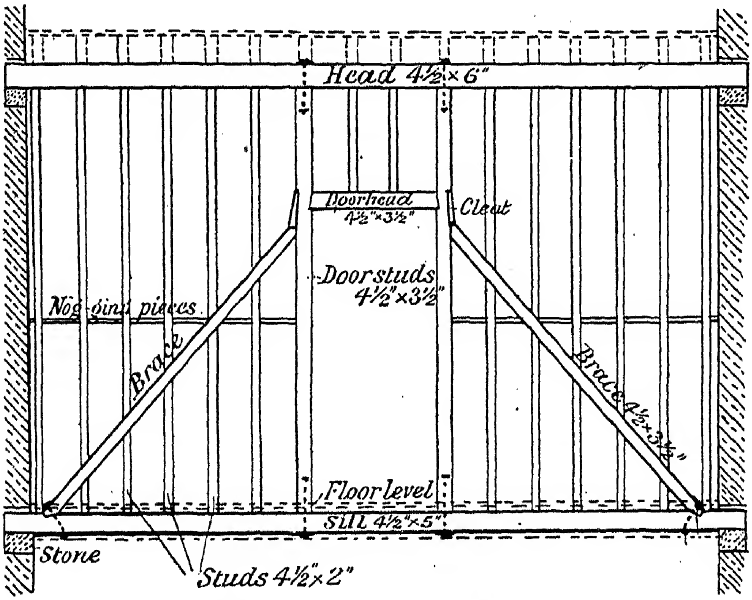


FIG. 254.—Line Diagram of a Framed Partition.



ELEVATION OF FRAMED PARTITION.

FIG. 255.

elevation of a framed partition with a central doorway,

seven feet by three feet ($7' \times 3'$), and has the names of the various parts indicated. In this case the partition runs in the direction of the floor joists of the lower floor, and has the sill, which is in one length, arranged between two joists. The upper floor joists are at right angles to the partition and are supported by it.

The stronger members of these partitions—that is, the head, sill, door-posts, and braces—are first framed together, the joints being secured with iron bolts or straps; the intermediate spaces are then filled with studs placed from twelve inches to fifteen inches (12″ to 15″) apart. Each brace should always be in one length, with the studs cut to fit on it. All

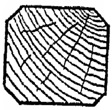


FIG. 256.

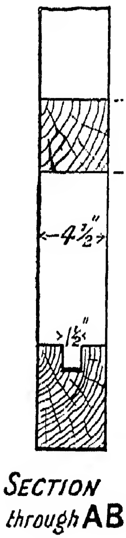


FIG. 257.

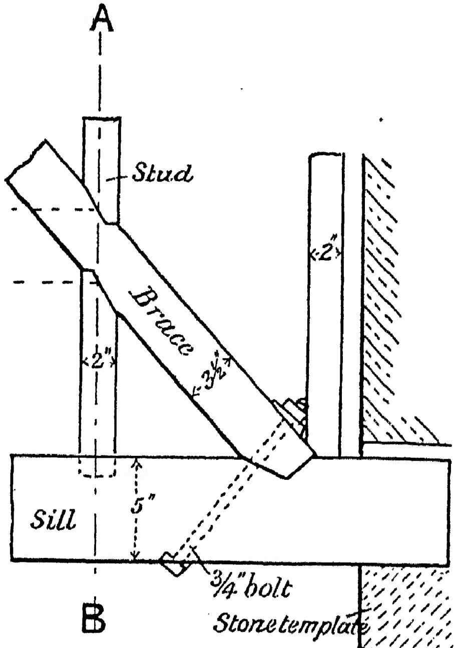


FIG. 258.

Joint at foot of Brace.

the joints should be arranged so that they are least affected by shrinkage, and all the thicker members of the partition, such as

door posts, braces, etc., should have the corners taken off (Fig. 256). Seasoned timber should always be used in the construction of partitions.

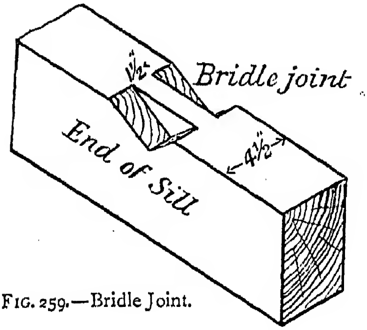


FIG. 259.—Bridle Joint.

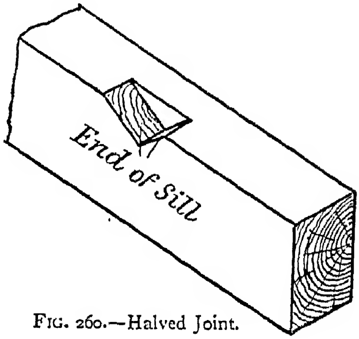


FIG. 260.—Halved Joint.

Joint at Foot of Brace.—Fig. 258 shows in elevation the joint at the foot of the brace. The joint may be *bridled*, as in Fig. 259, or may be *halved on* (Fig. 260). In either case a bolt is necessary to secure the connection.

Joint between Stud and Brace.—This joint may be simply cut to the required bevel and nailed (Fig. 261), or may be cut as shown in Fig. 258.

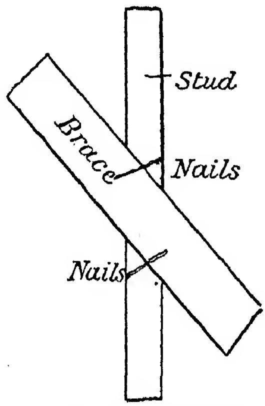


FIG. 261.—Joint between Stud and B

Joint between Stud and Sill.—This joint is made by a short tenon (named a *stump-tenon*) on the stud fitting into a corresponding mortise in the sill (Figs. 257 and 258). The ends of the door-posts, as well as the upper ends of the studs, are also stump-tenoned into the head or sill, as the case may be.

Joint at Head of Brace.—In Fig. 262 the door-post is wider above the door-head to allow for the abutment of the brace. This arrangement necessitates increased labour as well as a waste of material. An alternative method is to let in and nail a short piece of wood named a **cleat**. The brace abuts against this cleat

(Figs. 255 and 263). The door-head is stump-tenoned into the door-post (Figs. 262 and 263).

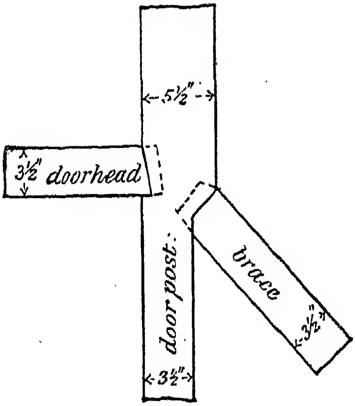


FIG. 262.

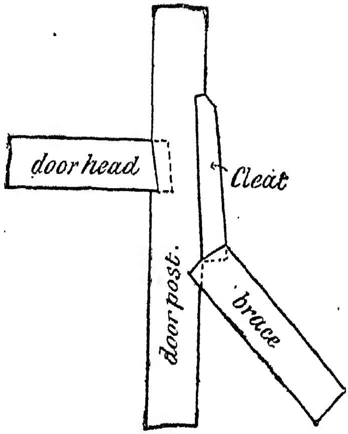


FIG. 263.

Alternative Joints at head of Brace.

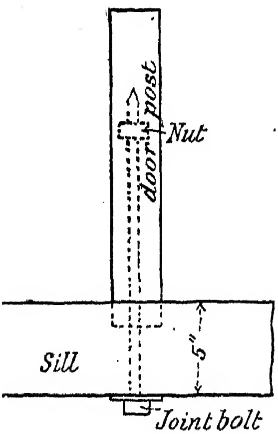


FIG. 264.

FIG. 265.
Section.

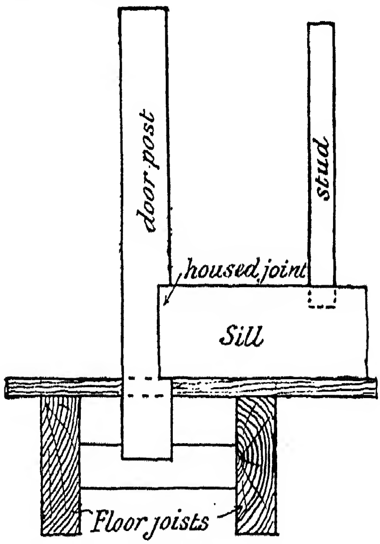


FIG. 266.

Alternative Joints at foot of Door-posts.

Joint at Head and Foot of Door-posts.—When the sill runs "straight through," as in Figs. 255 and 268, the lower

end of the door-post is stump-tenoned into it, and may be secured with a joint-bolt, as shown in elevation and section in Figs. 264 and 265. Or, it may have a wrought-iron strap to clip the sill and door-posts, with bolts passing through to fasten the joint. The objection to this latter method is that the bolts are liable to be in the way of the laths and plaster. The stump-tenon and joint-bolt are also used to secure the upper end of the door-post to the head (Fig. 255). When, as frequently happens, the partition runs across the joists of the lower floor, the sill cannot be continuous on account of the doorways (Figs. 267 and 270). Under such circumstances the sill is sunk or **housed** into the door-posts, these latter going between the joists, as shown in Fig. 266.

Partition with two Side Doorways. — Fig. 267 is the elevation of a partition with two side doorways. The horizontal member, which is continuous and forms the door-head, is named an *intertie*, and acts in this example as the

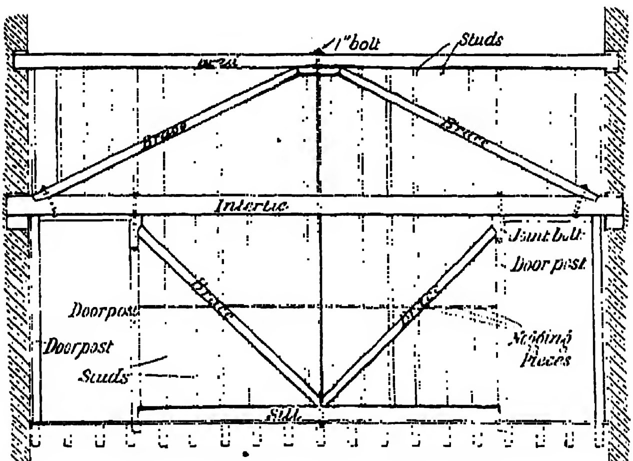
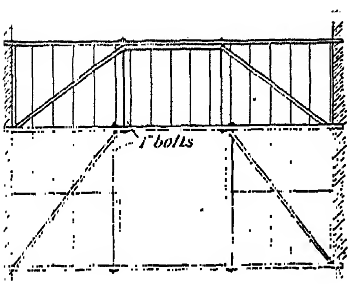


FIG 267.—Partition with Two Side Doorways.

main support of the partition. A long wrought-iron bolt, one inch (1″) in diameter, and having a nut at each end for tightening up, passes through the centre of the partition, as shown in the illustration. A strong wooden member might be substituted, and secured with stump-tenon joints and joint-

bolts in a manner similar to the joint at the head of the door-post (Fig. 255).

Figs. 268 and 269 are diagrams of other framed partitions. In these the stronger framing is shown with double lines, while the studs and horizontal nogging pieces are indicated by single lines. These diagrams represent typical examples of the manner in which partitions are framed. The size and



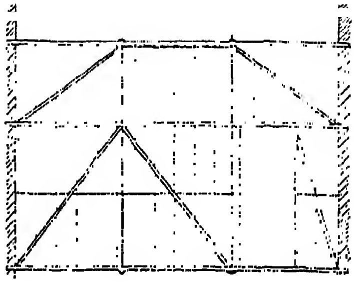


FIG. 268. FIG. 269.
Line Diagrams of Framed Partitions.

arrangement of the framing are, of course, dependent upon the width of span between the walls, the number, size, and

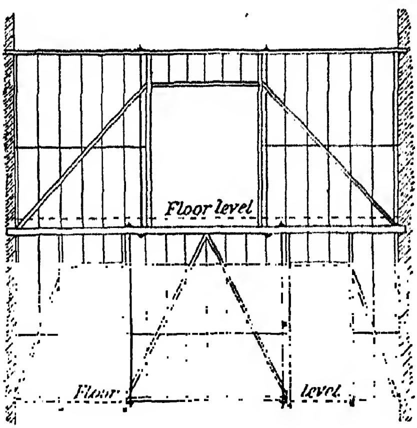


FIG. 270.—Two-story Framed Partition.

position of doorways, and the number, if any, of floors to be supported by the partitions. Fig. 270 shows a partition

extending through two stories in height, with a wide central doorway in the upper part and two smaller side doorways in the lower part. The joints of these partitions are arranged on the principles given in detail above, and therefore need not be further dealt with.

Brick-nogging.—The timber partition, instead of having the studs placed every twelve inches to fifteen inches (12″ to 15″) apart, may be fixed at intervals of two feet three inches (2′ 3″) or three feet (3′ 0″), and the intervening space filled with brickwork. Horizontal nogging pieces of wood one inch (1″) thick should be fixed at every third or fourth course. The usual thickness for brick-nogged partitions is four and a half inches ($4\frac{1}{2}$″), though often for the sake of economy or to gain room they are made three inches (3″) thick, having the brickwork laid on edge.

Summary

Partitions of wood covered with laths and plaster often take the place of brick walls between upper-story rooms. Such partitions are best framed into trusses directly transferring the weight to the walls.

The **framework** consists of horizontal members (*head*, *sill*, and *intertie*), vertical members (*door posts* and *studs*), and of inclined *braces*. All the members of the same truss should be of the *same thickness* to enable both sides to be plastered evenly.

Horizontal *nogging pieces* are fixed at intervals to stiffen the studs.

The joints mostly used for the framework of partitions are the *stump-tenon* and *bridle-joints* secured with bolts.

Brick-nogging consists of filling in the wooden framework with bricks.

Questions on Partitions

1. Draw, to a scale of $\frac{1}{2}$″ to the foot, the elevation of a framed partition dividing a room 16′ wide and 10′ high, and resting on stone templates built in walls 14″ thick. The partition has a central doorway 7′ 3″ × 3′ 3″ and carries the upper floor, the joists of both floors being at right angles to the partition. Head 7″ × $4\frac{1}{2}$″, sill 5″ × $4\frac{1}{2}$″, door-posts and door-head 4″ × $4\frac{1}{2}$″, braces $4\frac{1}{2}$″ × 3″, studs or quarterings $4\frac{1}{2}$″ × 2″, nogging pieces 4″ × $1\frac{1}{2}$″.

2. Draw the following details of the joints of the partition in Question 1 to a scale of $1\frac{1}{2}$″ to the foot :—

(*a*) Joint at foot of door-post (elevation).
(*b*) Joint at head of brace showing a cleat 10″ long (elevation).
(*c*) Joint at foot of brace showing the brace bridled on to the sill and secured with a ¾″ bolt (elevation and section).
(*d*) Joint between upper end of door-post and head of partition showing a ¾″ joint-bolt (elevation and section).
(*e*) Joint between sill and end of stud showing a stump-tenon (elevation and section).

Examination Questions

3. Elevation of a trussed partition between two rooms (Fig. 271).

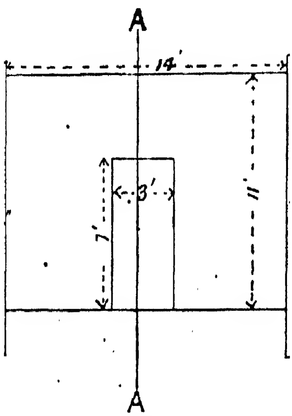


FIG 271

Draw, to a scale of $\frac{1}{24}$, the portion to the left of the line *A—A*, showing the following details, and how it is supported, as well as any ironwork you may consider necessary :—

Head 4½″ × 6″.
Sill 4½″ × 4″.
Quarters or studs 4½″ × 2″.
Door studs 4½″ × 3″.
Nogging pieces (one row) 4½″ × 2″.

4. Give an elevation, to a scale of 2′ to 1″, of a little more than half of a naked wooden trussed partition, 10′ high and 15′ long, with a 7′ × 3′ central doorway, from the following details: Sills 4″ × 5″, and resting 6″ on 3″ stone templates in 14″ brick walls; door studs 4″ × 4″; all other scantlings 4″ × 2″.

5. A room, 14′ wide, is to be divided in two by a quarter partition. It is to rest on the 4½″ × 3″ plates which carry the floor joists on brick offsets.

Give, to a scale of 2 feet to an inch, an elevation of the framing of the partition, showing a central opening 7′ × 3′ for a door.

The scantlings, which are to be marked on the different members, are to be as follows :—

Sills 4″ × 4″.
Studs or quarters 4″ × 2″.
Braces 4″ × 2″.
Door studs 4″ × 3″.

The details need not be filled in on both sides of the doorway.

* 6. Elevation of a $4\frac{1}{2}''$ trussed partition, to be constructed out c $9'' \times 3''$ and $9'' \times 2''$ deals (Fig. 272).

Give its elevation, to a scale of 3 feet to an inch, writing against them the names and scantlings of the different members.

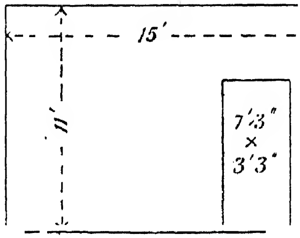


FIG. 272.

* 7. Sections of the sill and one of the studs of a lath - and - plaster framed partition (Fig. 273).

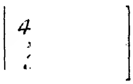


FIG. 273.

Draw, to a scale $\frac{1}{4}$ full size, a vertical cross section of the joint at the foot of the stud.

State what distance you would place the studs apart, and why

CHAPTER VII

WOODEN ROOFS

Slope of Roof.—The arrangement of the timbers or *scantlings* used in the construction of the roof of a building varies according to circumstances. Many considerations, such as the class of building, style of architecture, size of rooms, material to be used for covering, climatic conditions, etc., must be taken into account. Slates and tiles are most frequently used as coverings for roofs in this country. They require a sloping roof, the inclination of which ranges from twenty-five degrees (25°) to sixty-five degrees (65°) for slates, and from thirty-five degrees (35°) to sixty-five degrees (65°) for tiles. A common **pitch**, when slates are used, is one-fourth ($\frac{1}{4}$) or one-third ($\frac{1}{3}$) the span, which means that the vertical distance from the level of the top of the walls to the highest point of the roof is respectively one quarter ($\frac{1}{4}$) or one-third ($\frac{1}{3}$) the width of the building.

Other materials besides slates and tiles are often used for covering roofs, such as thatch, corrugated iron, asphalted felt, copper, zinc, lead, and concrete. Neither these materials, nor the arrangement of the roof for any of them, need be further dealt with here.

Parts of Roof.—The highest part of a roof sloping both ways is named the **ridge**; the horizontal piece of timber forming the ridge is called the **ridge piece** or **ridge tree.** The timbers placed in the direction of the slope of the roof are named **spars** or **common rafters.** These common rafters should be supported at intervals of not more than eight feet (8′) apart. The lower edges of a sloping roof are called the **eaves.** Wall-plates should be bedded on the wall at the

eaves to which to secure the lower ends of the common rafters. Intermediate horizontal timbers, which support the common rafters, are known as **purlins.**

Lean-to Roof.—The simplest kind of sloping roof is that where one wall is carried up sufficiently higher than the other to give the required slope to the roof. Such a roof is called a

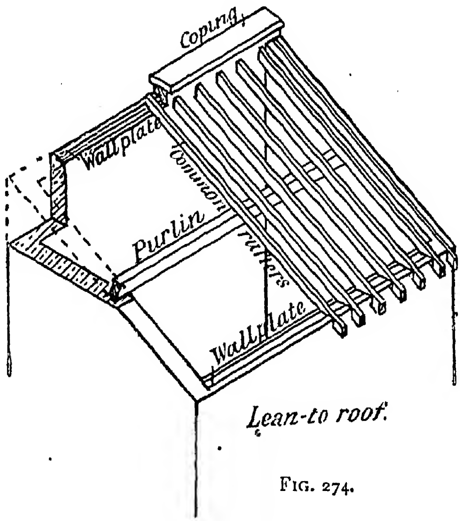


FIG. 274.

lean-to roof (Fig. 274). In all cases where the length of the common rafters is more than eight feet (8′), one or more purlins should be inserted.

Couple Roof.—A couple roof is one in which the common rafters slope upwards from opposite walls and meet a ridge piece in the middle. The common rafters are securely nailed to this ridge piece and to the wall-plate on each wall. The common rafters have no tie or other support in this class of roof. Such couple roofs are therefore only used when the span is not more than twelve feet (12′) (Fig. 275).

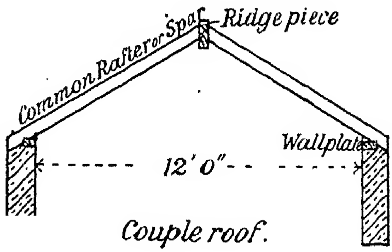


FIG. 275.

How Common Rafters are fixed.—In cottages and dwelling-houses generally, the inside walls of which are carried up to the roof, the common rafters are supported by purlins which extend from wall to wall. The size of the purlins varies according to the distance between the walls of support; they may either be placed with one side vertical, and with the top corner cut to the slope of the roof (Fig. 276), or as shown in

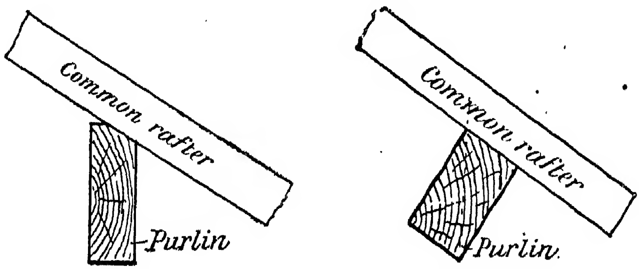
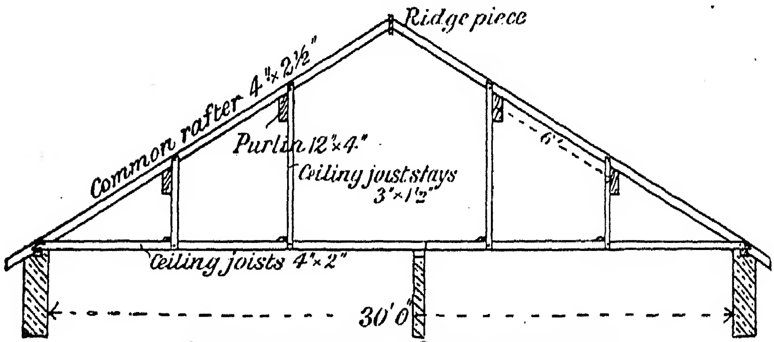


FIG. 276. FIG. 277.

Wooden Purlins supporting Common Rafters.

Fig. 277, with one side at right angles to the slope of the roof. When the purlins are placed as in Fig. 277, the proportion of the width to the thickness should be so adjusted that a diagonal of the cross section is vertical.

Ceiling.—The ceiling under the roof of an ordinary dwelling-house is obtained by fixing the ceiling joists, which are to carry the laths and plaster, level with the top of the



SECTION through the ROOF of a COTTAGE

FIG. 278.

side walls; or, to obtain additional height in the rooms, the ceiling joists may be placed part of the way up the slope of the roof. When securely nailed together and to the common rafters, these ceiling joists form a tie which strengthens the roof. To further stiffen them they are secured together and to the purlins with pieces of quartering, named **stays**, three inches by one and a half inches ($3'' \times 1\frac{1}{2}''$) (Fig. 278).

The roofs just described are used when the walls supporting the purlins are not more than sixteen feet (16′) apart; for greater spans up to twenty-two feet (22′), rolled steel or wrought-iron girders are commonly used as purlins. These steel or wrought-iron purlins require, however, pieces of timber bolting to the upper edge to which to secure the common rafters (Fig. 279).

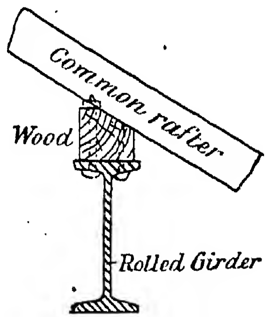


FIG. 279.—Iron Girder supporting Common Rafter.

Collar-beam Roof.—For spans between twelve feet (12′) and eighteen feet (18′) the collar-beam roof is extensively used. Its construction is effected by framing each pair of common rafters into a light truss and connecting them by means of a horizontal piece named a **collar-beam** (Fig. 280). The height of the collar-beam is determined by the amount of room required; the lower it is placed the stronger is the roof. It is usually fixed at one-third ($\frac{1}{3}$) or one-half ($\frac{1}{2}$) the vertical height from the wall to the ridge. The joint connecting the collar-beam to the rafter may be a *dovetail halved* joint (Figs. 281 and 282), or *halved and cogged* (Fig. 283). Both these joints require further securing with bolts.

The lower end of the rafter is cut and nailed to the wall-plate as in Fig. 284, or if the rafter overhangs the wall, it is cut as shown in Fig. 285. Both these joints are known as *bird's-mouth* joints.

Each pair of common rafters is connected at the upper end by means of a **cleat**, and has a slot to receive the ridge piece (Fig. 286).

King- and Queen-post Trusses.—When the span exceeds eighteen feet (18′), and there are no inside supporting

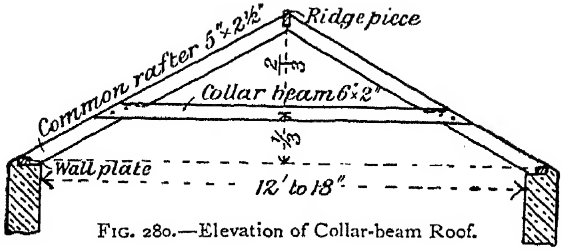


FIG. 280.—Elevation of Collar-beam Roof.

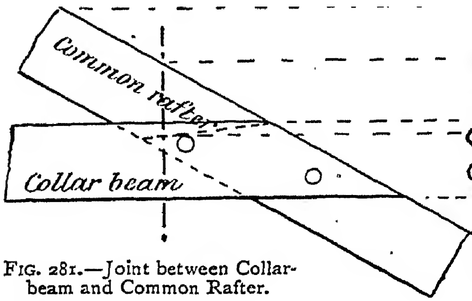


FIG. 281.—Joint between Collar-beam and Common Rafter.

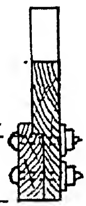


FIG. 282. Section.

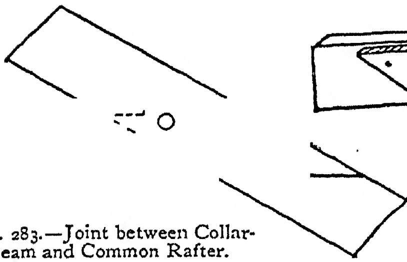


FIG. 283.—Joint between Collar-beam and Common Rafter.

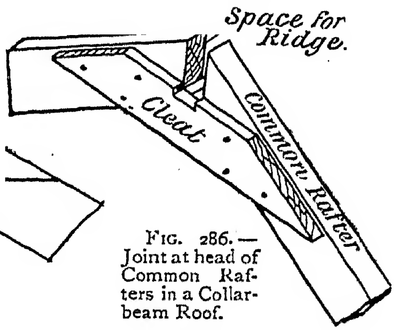


FIG. 286.—Joint at head of Common Rafters in a Collar-beam Roof.

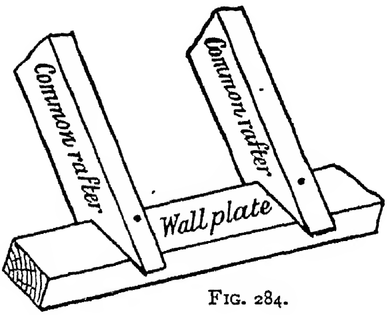


FIG. 284.

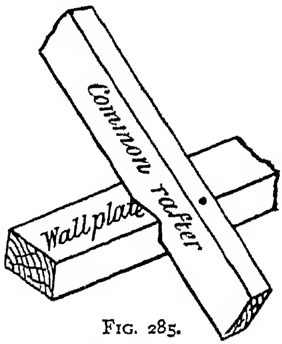


FIG. 285.

Bird's-mouth Joints at foot of Common Rafters.

walls for the purlins, framed structures known as **King-post** or **Queen-post** trusses are used. Such trusses are placed about ten feet (10′) apart, and carry the ridge piece and the purlins on which the common rafters rest. The principle that the common rafters must not have more than eight feet (8′) of unsupported length determines whether the truss for a given

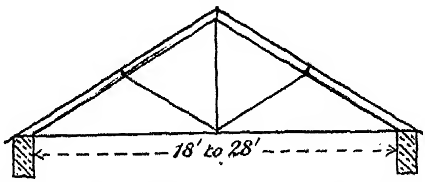


FIG. 287.—Line Diagram of a King-post Roof Truss.

span shall be of the King-post or Queen-post type. Figs. 287 and 288 are line diagrams of King-post and Queen-post trusses respectively. In a King-post truss with a span of from eighteen to twenty-eight feet (18′ to 28′), and a pitch of one quarter ($\frac{1}{4}$), the common rafters will not exceed sixteen feet (16′) in length, and one purlin will therefore be sufficient. With a greater span than twenty-eight feet the common rafters will

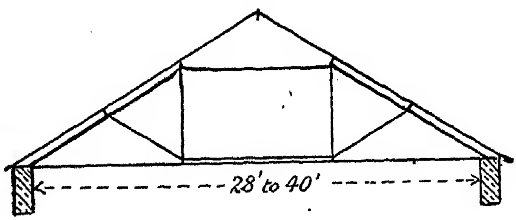


FIG. 288.—Line Diagram of a Queen-post Roof Truss.

generally be more than sixteen feet long, and will require two or more purlins on each side of the roof. In order that each purlin may be directly supported, the Queen-post truss is then necessary.

The joints of all wooden roof trusses should be arranged, as far as possible, at right angles to the grain of the wood, so that they will be least affected by shrinkage.

King-post Truss.—Fig. 289 shows the elevation of a King-post truss with the names of the different members

appended. As will be noticed, the truss derives its name from the central upright, called the **King-post.** The horizontal member, or **tie-beam,** prevents the **principal rafters**

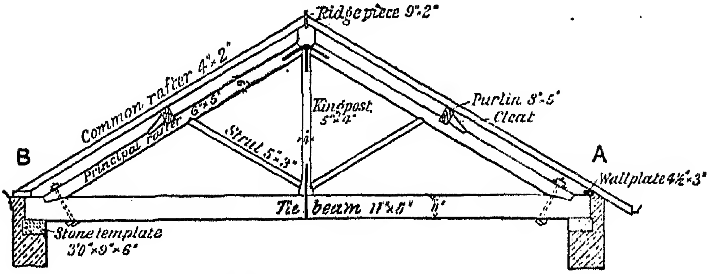


FIG. 289.—Elevation of King-post Roof Truss.

from spreading. The **struts** are arranged to support the principal rafters at points beneath the purlins.

Joint at Foot of Principal Rafter.—This joint should be directly over the wall, as shown in Fig. 291, or if it be

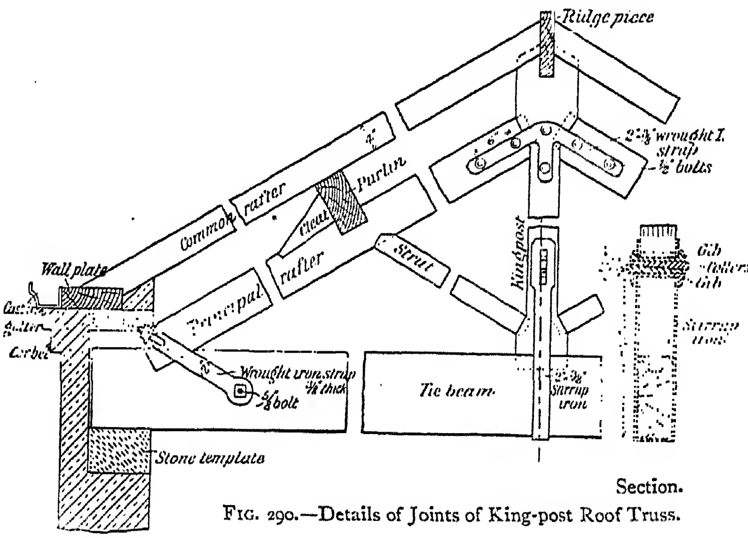


FIG. 290.—Details of Joints of King-post Roof Truss.

necessary to have it some distance from the wall, as in Fig. 292, a stronger tie-beam will be required, since additional stress is, in such a case, put on that member. Figs. 290, 293, and 294

show three different ways of making the connection between tie-beam and principal rafter. In each case the end of the principal rafter is cut at right angles to ~~the grain of the~~ wood for half its width. In Fig. 293 an additional stump-tenon (p. 85) is formed on the end of the principal rafter; in Figs. 290 and 294 the middle part of the principal rafter is cut out and forms a bridle joint (p. 214). An iron bolt may be used to secure the joint (Fig. 289), or wrought-iron straps are sometimes employed, as in Figs. 290 and 298.

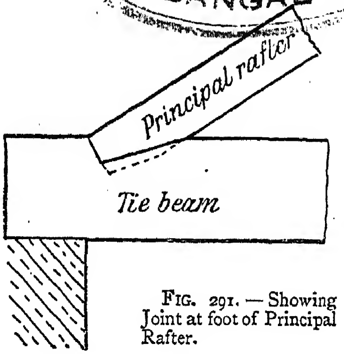


FIG. 291. — Showing Joint at foot of Principal Rafter.

Joint at Head of King-post. — Fig. 290 shows the elevation of the joint between the upper ends of the principal rafter and the King-post. The principal rafter is stump-tenoned into the King-post, the joint being secured by a wrought-iron strap on each side, which is bolted through each member as shown in the illustration.

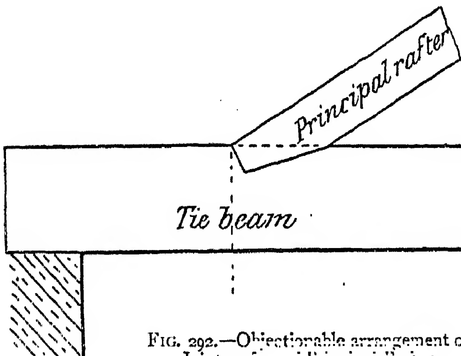


FIG. 292.—Objectionable arrangement of Joint at Foot of Principal Rafter.

Joint at End of Strut.—The strut has the upper end either bridled or stump-tenoned into the lower edge of the principal rafter, and the lower end stump-tenoned into the lower end of the King-post, which is mortised to receive it, as shown in Fig. 290.

Joint between King-post and Tie-beam.—The lower end of the King-post is tenoned into the upper edge of the tie-beam for a distance of about two inches (2″), and is secured with either—

(*a*) A ⊔-shaped *wrought-iron* strap, embracing the tie-beam and King-post, and called a *stirrup iron.* The stirrup iron is held in position by iron clips called *gibs*, and iron wedges called *cotters.*

(*b*) A joint bolt.

(*c*) Wrought-iron strap and bolts.

When the truss is constructed, the joint between the King-post and tie-beam is left about one inch (1″) slack, and the

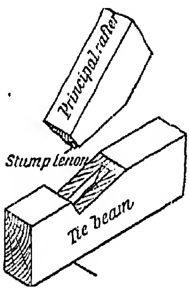


FIG. 293.

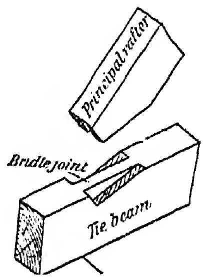


FIG. 294.

Sketches of Joints at foot of Principal Rafter.

iron fastening used is so arranged that in tightening up it draws all the joints together, thus causing the tie-beam to have a little *camber* or curve to allow for any subsequent settlement.

Stirrup iron with Gibs and Cotters.—Fig. 295 shows a sketch of the stirrup iron with gibs and cotters ready for tightening up, two gibs and two cotters being used. It is necessary to carefully note the spaces left for tightening up which are shown in Fig. 295. The lower gib rests on the wooden King-post, and brings it down towards the joint; the upper gib binds against the iron stirrup, and in this way draws the tie-beam towards the joint; so that when the cotters are driven tight they draw the joint together.

Straps and Bolts.—A **joint-bolt** is a bolt about three-quarters of an inch ($\frac{3}{4}$″) in diameter, and of length equal to

about twice the depth of the tie-beam. Its pointed end has a thread from three to four inches (3″ to 4″) long, which goes into a flat nut let into the King- or Queen-post (Figs. 298 and 299).

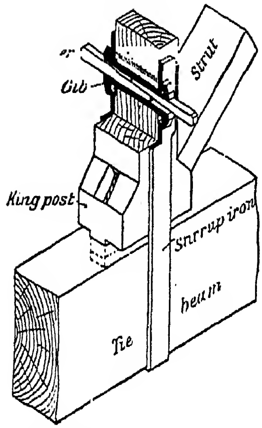


FIG. 295.—Sketch of Joint at foot of King-post showing Stirrup Iron with Gibs and Cotters.

FIG. 296.

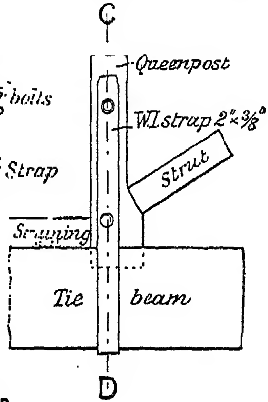


FIG. 297.—Foot of Queen-post showing W.I. Straps and Bolts.

The strap and bolts, shown in Figs. 296 and 297, consist of a wrought-iron strap bent to clip the tie-beam and post. The arrangement is secured in position by bolts.

The ends of all tie-beams should rest on stone templates and have air-spaces around them as described for floor girders (p. 72).

Queen-post Truss.—The elevation of a Queen-post truss

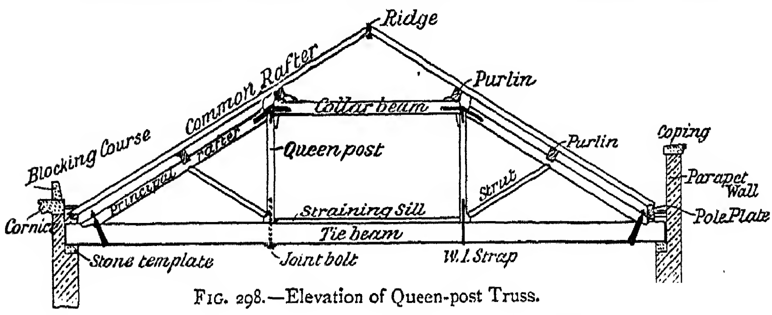


FIG. 298.—Elevation of Queen-post Truss.

is shown in Fig. 298, with the names of the different members indicated. This truss differs from a King-post truss in having

two vertical members (Queen-posts), the upper ends of which are kept in position by a horizontal **collar** or **straining beam.** Another member which is not found in the King-post truss is the **straining sill.** It is inserted on the tie-beam, between the Queen-posts, to counteract the thrust of the struts. The joints of this truss are made similar to those described for the King-post truss, with the exception of the joint at the head of the Queen-post. This joint is shown in elevation in Fig. 299. The lower end of the Queen-post has a strut mortised into it on one side only.

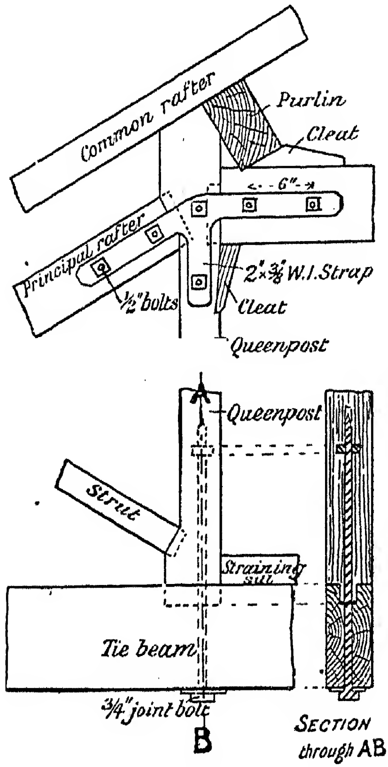


FIG. 299.—Details of Joints at head and foot of Queen-post.

Joint between Purlin and Principal Rafter.—The purlins are cogged (p. 71) to the backs (upper edges) of the principal rafters, additional support being obtained by housing a cleat (p. 85) into the back of each principal rafter, and resting it against the purlin as shown in Fig. 290. When the slope of the roof is steep, the common rafters are frequently notched about three quarters of an inch on to the upper edge of the purlin (Fig. 300).

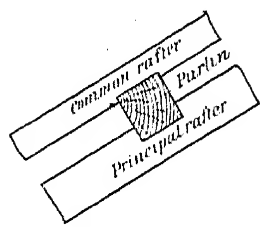


FIG. 300.—Section through Wooden Purlin.

Eaves of Roof.—The eaves of roofs are finished in different ways. Fig. 289 at *B* shows the

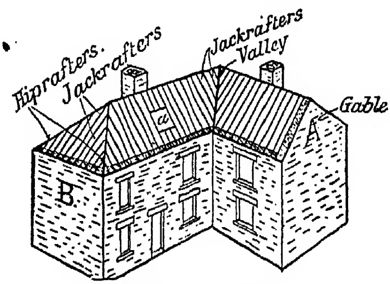
common rafter finishing on the wall-plate, with the rain-water gutter resting partly on the wall, which is corbelled out (p. 64). The gutter is sometimes carried by projecting brick or stone corbels (p. 45) placed from two to three feet apart.

Overhanging Eaves.—Fig. 289 at *A* shows the eaves overhanging the wall. This method affords a means of protecting the wall from the weather. The projection varies considerably, and may be anything from four inches to two feet (4″ to 2′). The eaves gutter may be carried by wrought-iron straps nailed to the common rafters; or a wide vertical board, named a **fascia board**, may be nailed to the ends of the common rafters. The fascia board has a mould secured to it, and this supports the eaves gutter (Fig. 384).

Parapet Wall.—Fig. 298 shows on its right side a wall reduced in thickness, and continued up above the level of the roof. Such a wall is known as a **parapet wall.** In these circumstances a gutter is formed behind the wall, and the lower ends of the common rafters are carried by a horizontal beam similar in size to a purlin. **Pole-plate** is the distinctive name given to this beam. This arrangement of the roof timbers is also applicable when the eaves are finished with a stone cornice and blocking-course (Fig. 298).

Hips and Valleys.—A **hip** is an angle made when a building, instead of having a gable, as at *A* (Fig. 301), has the roof returned round the end of the building as at *B*.

A **valley** is formed when two roof surfaces meet together and form an internal angle. Hips and valleys are constructed with strong timbers placed on edge, and carried by the walls or roof trusses. They are named *hip or valley rafters*, and carry the common rafters that abut against them. The latter are known as *jack rafters*.



G. 301.—Sketch showing Gal Roof, Hip and Valley Rafters, etc.

Trimming.—When roof-lights, chimney shafts, large ventilators, etc., occur on a roof, the common rafters around

them require framing. This method of framing is named trimming, and is shown in Fig. 301 at *a;* the joint employed is the mortise and tenon joint.

Ceiling Joists.—When roof trusses are used, and a plaster ceiling is required, the ceiling joists may

(*a*) be notched and nailed to the under side of the tie-beams;

(*b*) rest on wooden fillets nailed to the side of the tie-beam so as to come either level with the under side or part way up the beam;

(*c*) rest on the tops of the tie-beams.

Combined Wood and Iron Trusses.—Roof trusses are often constructed with a combination of wood and iron.

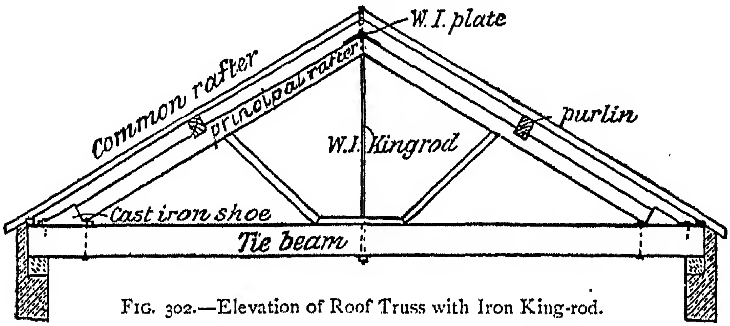


FIG. 302.—Elevation of Roof Truss with Iron King-rod.

In such cases the iron members are those in tension, or in other words, those tending to stretch. Iron members in roof trusses impart an appearance of lightness without sacrifice of strength, and when used with iron connections also make it practicable to use simpler joints. The main objection to this class of truss is that whilst the iron is affected by varying temperatures and expands with heat, the wood is practically not affected. This difference of behaviour renders the truss liable to be overstrained in parts. Again, plaster ceilings cannot conveniently be secured when an iron tie-rod takes the place of the tie-beam.

Fig. 302 shows the elevation of a truss suitable for spans up to twenty-eight feet (28′), where an iron King-rod takes the place of the King-post.

Fig. 303 shows a modified form of collar-beam truss with iron

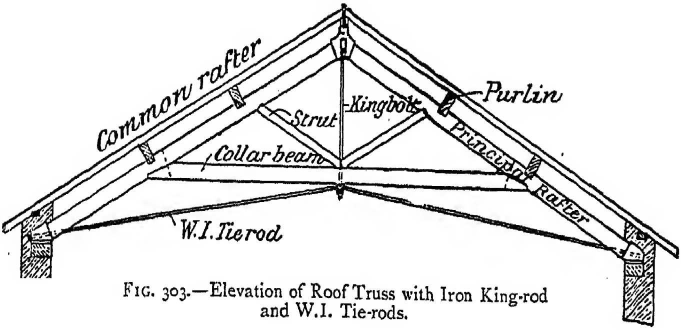


FIG. 303.—Elevation of Roof Truss with Iron King-rod and W.I. Tie-rods.

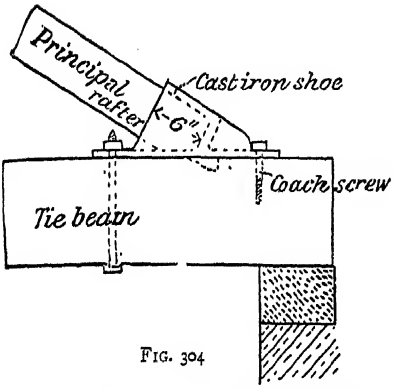


FIG. 304

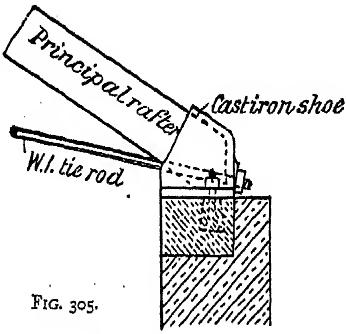


FIG. 305.

Alternate arrangements at foot of Principal Rafter.

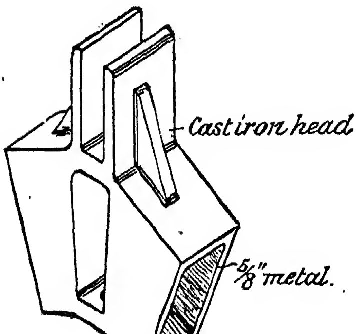


FIG. 306.—Sketch of Cast-iron Head for Joint at head of Principal Rafters and King-rod.

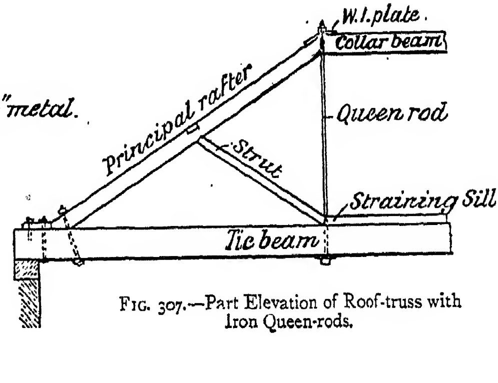


FIG. 307.—Part Elevation of Roof-truss with Iron Queen-rods.

tension rods instead of the tie-beam, and with a King-rod replacing the wooden King-post.

Figs. 304 and 305 show different connections at the foot of the principal rafter.

Fig. 306 is a sketch of the cast-iron head used at the upper end of the principal rafters in Fig. 303.

Fig. 307 shows the elevation of about half of a truss with

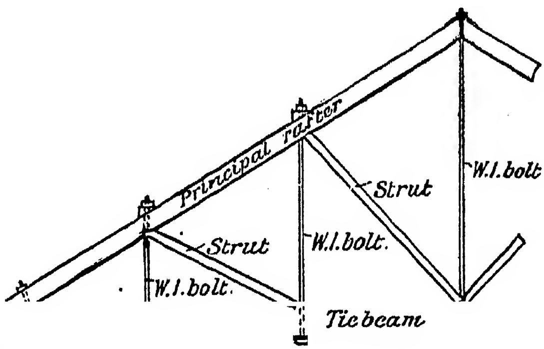


FIG. 308.—Part Elevation of Composite Roof Truss for Span of 40′.

Queen-rods instead of Queen-posts; while a truss for a larger span may be constructed as shown in Fig. 308.

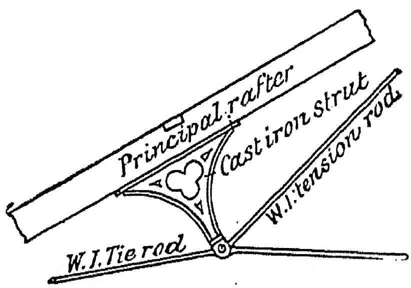


FIG. 309.—Details of Cast-iron Strut and W.I. Tension- and Tie-rods.

Fig. 309 shows an ornamental cast-iron strut for a roof truss, whose only wooden members are the principal rafters.

Summary

Wooden roofs may be *lean-to* or *ridged roofs*.

Ridged roofs are *couple* (for spans up to 12′), *collar beam* (up to 18′), *King-post* (up to 28′), or *Queen-post* for larger spans (up to 40′).

Purlins.—The sloping part of the roof consists of common rafters resting on purlins. In dwelling-houses the inner walls are generally sufficiently near each other to support the purlins. In larger buildings the purlins are carried by King- or Queen-post trusses placed about 10′ apart. The purlins should not be more than 8′ apart, and when a truss is used it should be so designed as to directly support each purlin.

The **joints** of the truss are made so as to be least affected by the shrinkage of the timber.

Roof trusses may often with advantage have the tension members of wrought iron.

Questions on Wooden Roofs

1. Draw a cross section to a scale of $\frac{3}{8}''$ to the foot through the roof of a building of 24′ span, with walls 14″ thick, showing the roof timbers supported by a King-post truss. The eaves on one side to be finished with a 9″ parapet wall surmounted by a weathered and throated stone coping 6″ thick, and the eaves on the other side to overhang the wall for a distance of 12″. Scantlings as follows: tie-beam $11'' \times 5''$; principal rafters $6'' \times 5''$; King-post $4'' \times 5''$; struts $3'' \times 5''$; purlins $8'' \times 5''$; common rafters $4'' \times 2\frac{1}{4}''$; pole-plate $8'' \times 4''$; ridge piece $9'' \times 2''$; wall-plate $4\frac{1}{2}'' \times 3''$.

2. Draw details of all the joints of the truss of Ques. 1 to a scale of $1\frac{1}{2}''$ to the foot, using $2'' \times \frac{5}{16}''$ wrought-iron straps and $\frac{1}{2}''$ bolts for head of King-post; $2'' \times \frac{3}{8}''$ stirrup iron, with gibs and cotters at foot of King-post; and $\frac{3}{4}''$ bolts to secure the joints at foot of principal rafters.

3. Draw the elevation of a Queen-post roof truss for a 35′ span from the following data: tie-beam $10'' \times 5''$; principal rafters $6'' \times 5''$; straining beam $8'' \times 5''$; Queen-posts $4'' \times 5''$; struts $3'' \times 5''$; straining sill $3'' \times 5''$.

The truss to rest on 6″ stone templates in 18″ brick walls and to carry $9'' \times 4\frac{1}{2}''$ purlins and pole-plates, $3\frac{1}{2}'' \times 2''$ common rafters, and a $9'' \times 2''$ ridge piece.

The eaves on one side to be finished with a stone cornice (9″ thick) and blocking course, and on the other side to have three over-sailing courses of brickwork arranged to carry the eaves gutter. Scale $\frac{1}{4}'' =$ 1 foot.

4. Draw the details of the joints of the truss (Ques. 3) to a scale of $\frac{1}{12}$ full size, including a wrought-iron strap ($2'' \times \frac{3}{8}''$) securing the joint at the foot of principal rafter; $2'' \times \frac{3}{8}''$ wrought-iron straps

and $\frac{5}{8}''$ bolts at head of Queen-post, and a $\frac{7}{8}''$ joint-bolt at foot of Queen-post.

* 5. A line diagram of a roof truss is given (Fig. 310).

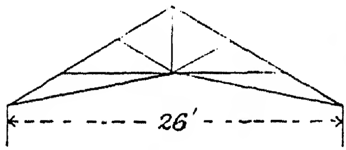


FIG. 310.

Draw an elevation, to a scale of $\frac{1}{2}''$ to the foot, from the following details: principal rafters and collar beam $8'' \times 5''$; struts $3'' \times 5''$; tie-rods $1\frac{1}{4}''$ diameter; King-rod $1''$ diameter; cast-iron head and shoe connections.

6. Draw, to a scale of $\frac{1}{6}$ full size, the details of the joints at the head and foot of the principal rafter in Ques. 5.

7. Draw line diagrams of trusses suitable for spans of 10′, 16′, 24′, and 32′ respectively. Name the various parts, and show all members that would be in compression by double lines. Scale, $\frac{1}{72}$ full size.

EXAMINATION QUESTIONS

8. Draw, to a scale of 3′ to 1″, a cross section through a couple roof, resting on 9″ brick walls 12′ apart. Rafters and wall-plates to be $4'' \times 2''$, ridge board $7'' \times 1\frac{1}{2}''$. Only the four top courses of the walls to be shown, with the eaves projecting 9″.

9. Draw, to a scale of 3′ to an inch, an elevation of a wooden collar roof over a 16′ span.

Rafters to be $4\frac{1}{2}'' \times 2''$, collar $4\frac{1}{2}'' \times 2''$, ridge board $8'' \times 1\frac{1}{2}''$, wall-plate $4\frac{1}{2}'' \times 3''$. Eaves to overhang one and a half brick walls 9″.

* 10. Line diagram of a timber roof with a rise of $\frac{1}{3}$ the span, the rafters being $3\frac{1}{2}'' \times 2\frac{1}{2}''$, and the collars $4\frac{1}{2}'' \times 2''$ (Fig. 311).

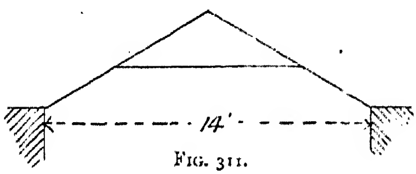


FIG. 311.

Draw, to a scale of $\frac{1}{2}''$ to a foot, a little more than half of same, showing how it would rest with overhanging eaves on a 9″ brick wall.

The joint between the collar and the rafter is to be shown in detail, and must be made so as not to weaken the rafter.

Give the name by which the roof is known.

11. Draw, to a scale of $\frac{1}{48}$, skeleton diagrams showing the difference between the following descriptions of open timber roofs in their

simplest forms. All members below the slate boarding to be indicated, with their names.

(*a*) A couple roof.

(*b*) A collar-beam roof.

(*e*) A King-post roof.

12. Draw single line diagrams to a scale of 8 feet to an inch, showing the ordinary forms of timber roof trusses used for spans of 18′, 25′, and 40′ respectively.

Give the names of the trusses, and of their different members.

13. Draw a line diagram, to a scale of $\frac{1}{60}$, of an ordinary timber roof truss suitable for a 25 feet span, showing the purlins, pole-plate, ridge board, and common rafters in their proper positions.

14. Draw, to a scale of $\frac{1}{96}$, a line diagram showing a Queen-post roof truss for a span of 36 feet, with a rise of $\frac{1}{4}$ span.

Write their names against the different members.

State why a King-post truss should not be used for this span.

15. Draw, to a scale of 2′ to an inch, the elevation of about one-half of a roof truss for a 26′ span, showing the following details, the rise being quarter the span :—

Wall plates $4\frac{1}{2}'' \times 3''$.
Principals $5'' \times 4''$.
Tie-beam $11'' \times 5''$.
Struts $4'' \times 3''$.
King-post $5'' \times 4''$.
Purlins $8'' \times 5''$.
Pole-plates $8'' \times 3''$.

*16. Joint between the foot of a principal rafter and the tie-beam of a wooden roof truss, showing the end of the tie-beam resting on a brick wall (Fig. 312).

Draw, to a scale of 2′ to an inch, making any alterations you consider necessary, and adding a heel-strap 2″ wide.

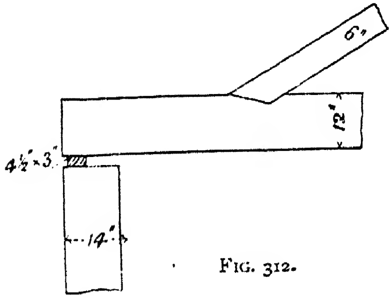


FIG. 312.

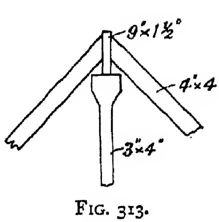


FIG. 313.

*17. Joint at the head of a small wooden roof truss (Fig. 313).
Draw, to a scale of $\frac{1}{12}$, making any corrections you may consider

necessary. Write its name against the truss, and against each of the members shown.

* 18. Head of a King-post in a wooden roof truss (Fig. 314).

Draw, to a scale of $\frac{1}{8}$, adding the heads of the principals $6'' \times 4''$, and a ridge board $11'' \times 2''$, and making any alteration you think necessary.

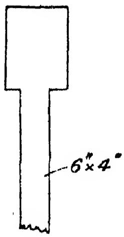


FIG. 314.

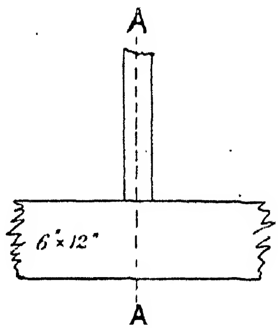


FIG. 315.

* 19. Elevation of the joint at the foot of a King-post in a wooden roof truss (Fig. 315).

Draw, $\frac{1}{4}$ full size, a section through *A—A*, showing all the details of a stirrup iron properly keyed up with gibs and cotters.

20. Draw, to a scale of 3′ to an inch, an elevation of a little more than half of a Queen-post roof truss for a 35′ span, from the following details :—

Tie-beam $5'' \times 9''$.
Principals $5'' \times 6''$.
Queens $5'' \times 3''$.
Straining beam $5'' \times 8''$.
Stirrup irons and heel-straps to be $2'' \times \frac{1}{4}''$.

* 21. Parts of a roof truss (Fig. 316). One member of each kind being given.

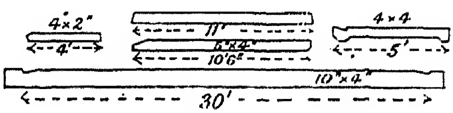


FIG. 316.

Draw the truss to a scale of 4 feet to an inch, writing down the names of the truss and of its different members, including any iron work.

Elevation of one of the joints at the head of an ordinary timber roof truss (Fig. 317).

Draw the same properly to a scale of $\frac{1}{6}$, showing the details of the joint, including a 2″ wrought-iron strap, and giving the names of the members shown.

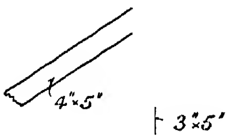
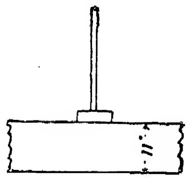


FIG. 317.



. 318.

*23. Elevation of the foot of an iron King-rod in a timber roof truss (Fig. 318).

Draw, to a scale of $\frac{3}{4}''$ to a foot, adding $4\frac{1}{2}'' \times 2''$ struts, and any other details necessary to complete the joint.

24. Draw, to a scale of 6′ to an inch, a single line diagram showing the form of a King-post roof truss for a 30′ span, the rise being $\frac{1}{4}$ the span. Write their names on the different members, and draw, $\frac{1}{6}$ full size, an elevation of the joint at the top of the truss, the members consisting of a cast-iron head, $5'' \times 5''$ timbers, and an iron rod $1\frac{1}{4}''$ diameter.

CHAPTER VIII

IRON ROOF TRUSSES

Iron Roof Trusses.—Iron trusses, instead of wooden ones, are now extensively used for carrying the roofs of such buildings as warehouses, sheds, workshops, railway stations, etc., where open roofs are preferable to those having plaster ceilings. Their lightness of appearance, their smaller liability to destruction by fire, and their freedom from those diseases which seriously affect wood, are all important points in their favour. Trusses of the kind under consideration consist largely of wrought iron or steel, though cast iron is frequently employed for struts and connections. The shape of an iron truss should be so designed that each of its members is subject to a direct stress, either of tension or compression.

Stresses in the different parts of a Truss.—Although a knowledge of geometry and mechanics is necessary to *thoroughly* determine and understand all the stresses to which a roof truss is subject, it is an easy matter to find out whether any particular member of a truss is in tension or compression, simply by considering whether a rope could or could not take its place without impairing the strength of the truss.

Example.—The weight on the truss (Fig. 319) is caused by the weights *W*, *W*, *W*, where purlins (p. 93) and ridge piece (p. 92) rest. These weights have a tendency to spread the feet of the truss, as is shown by the dotted lines, but are prevented from so doing by the tie rod marked *B*, *B*. Since a rope could take the place of the tie rod *B*, *B*, without affecting the strength of the truss, we may at once say that the tie rod *B*, *B*, is in tension. Neither of the principal rafters, *A*, *A*, could be replaced by ropes, therefore *A*, *A*, are both in

Fig. 319.

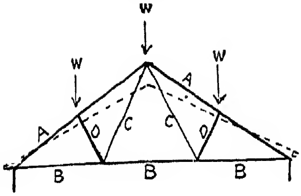
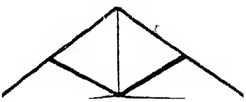


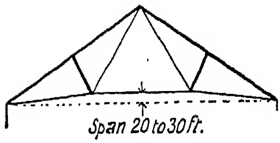
Fig. 320.

Span up to 15 ft.



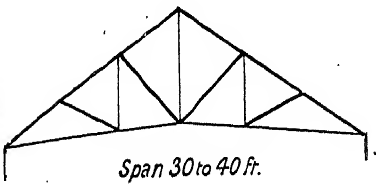
Span 20 to 30 ft.

Fig. 321.



Span 20 to 30 ft.

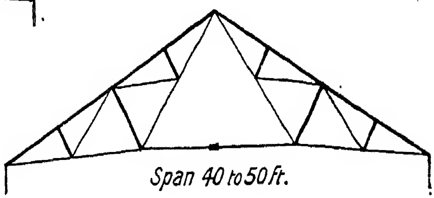
Fig. 322.



Span 30 to 40 ft.

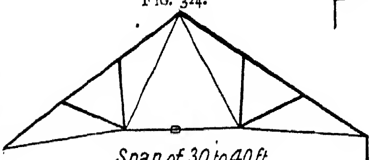
Fig. 323.

Fig. 326.

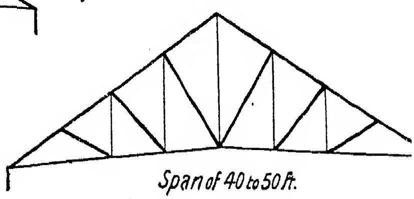


Span 40 to 50 ft.

Fig. 324.

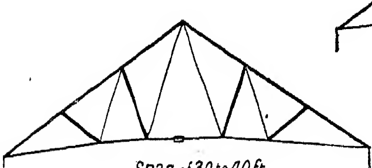


Span of 30 to 40 ft.



Span of 40 to 50 ft.

Fig. 327.



Span of 30 to 40 ft.

Fig. 325.

Line Diagrams of typical Trusses.

compression. Again, the struts D, D support the principal rafters under W, W, and are themselves supported in turn by rods C, C, from the upper ends of the principal rafters. Thus, since ropes could take the place of the rods C, C, but not of the struts D, D, we can say that the rods C, C are in tension, and the struts D, D are in compression. Other trusses may be considered in a similar manner, and the nature of the stress in each of their members determined.

Typical Trusses.—The line diagrams, Figs. 320 to 327, show typical examples of the trusses used for various spans. The members of the various trusses which are in compression are shown by thick lines, while the thin lines show the members in tension. The number, size, and relative position of the different members composing each roof truss are dependent on—(1) the span; (2) the pitch of the roof; and (3) the material used for covering it. As they are in compression, the struts of all these trusses should be arranged so that they are as short as possible. With this object the tie rods are raised in the middle to the extent of about one-thirtieth ($\frac{1}{30}$) of the span. This rise is called **cambering**. The tie rods in small trusses may be in one length. In large trusses, however, they are frequently made in two, three, or more lengths.

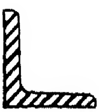


FIG. 328. Angle Iron.

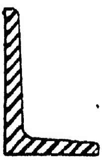


FIG. 329. L Iron.

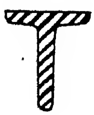


FIG. 330. T Iron.

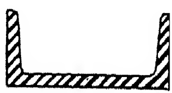


FIG. 331. Channel Iron

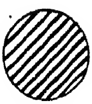


FIG. 332 Round Iron.

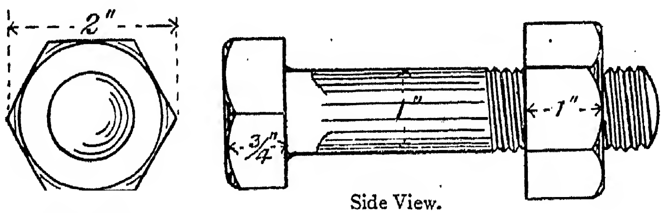

FIG. 333 Cross-section Iron.


FIG. 334. Flat Bar Iron

Sections of various members.—Figs. 328 to 334 give sections of steel or wrought iron used in the construction of

roof trusses. The most suitable section for principal rafters is T iron (Fig. 330). For struts either L iron (Fig. 329), angle iron (Fig. 328), channel iron (Fig. 331), flat bar iron (Fig. 334), or cross-section iron (Fig. 333) may be used. When struts made of cast iron are used, the cross-section iron is the best. The tension and tie rods (which are invariably made of either wrought iron or steel), may be either round or flat in section.

Connections.—The connections, which must each be considered in detail, may be of cast or wrought iron. Bolts are used as fastenings with cast-iron connections; though where wrought-iron plates are employed, rivets may often be used with advantage. Bolts used as fastenings look best when the head and nut are of hexagonal shape. Fig. 335 gives the



End View. Side View.

Fig. 335.—Proportions of a Bolt.

proportions of a bolt, which it is advisable that the student should notice carefully. The thickness of the head is equal to three-quarters ($\frac{3}{4}$) of the diameter of the bolt; the distance from opposite corners across either the head or the nut is twice the diameter of the bolt, while the thickness of the nut is equal to the diameter of the bolt.

The ends of tension rods are often threaded, and nuts fitted to these threaded ends to form connections. When these threads are cut as in ordinary bolts (Fig. 335), they reduce the strength of the rod, and are known as *minus threads*. If, however, the end of the rod is originally made thicker, and the thread is cut on the thicker part, as shown in Fig 336, the

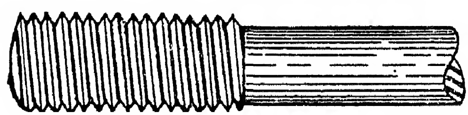


Fig. 336.—End of Tension Rod with a Plus Thread.

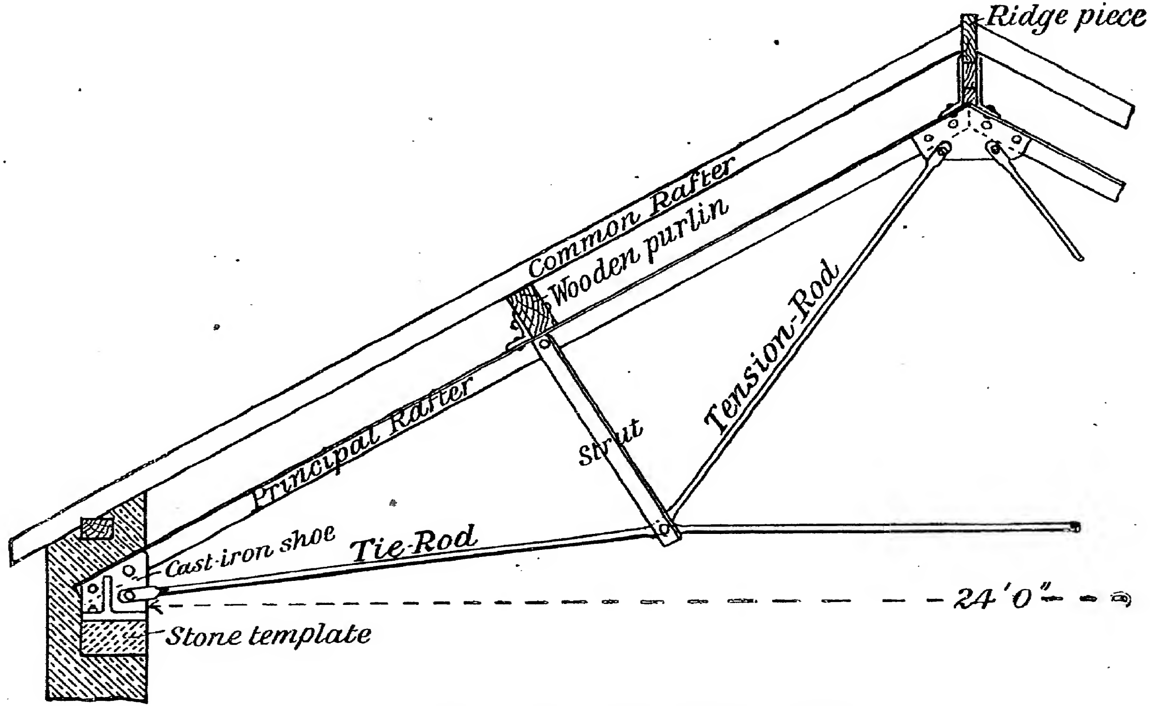
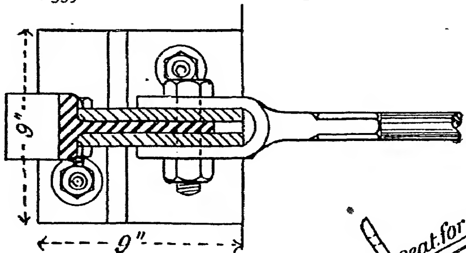


FIG. 337.—Part Elevation of an Iron Roof Truss for a 24′ Span.

FIG. 339.—Horizontal Section through x—y, Fig. 338.



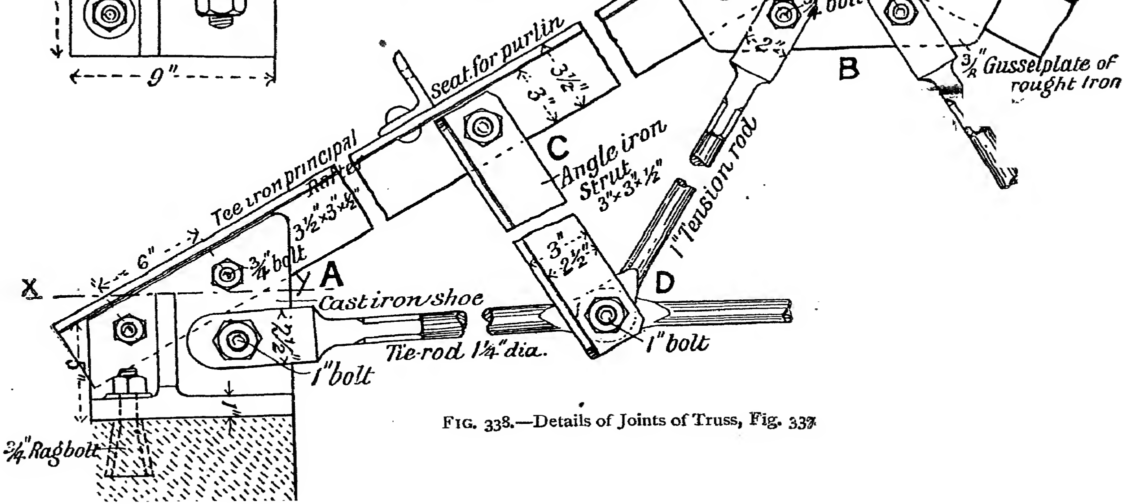


FIG. 338.—Details of Joints of Truss, Fig. 337.

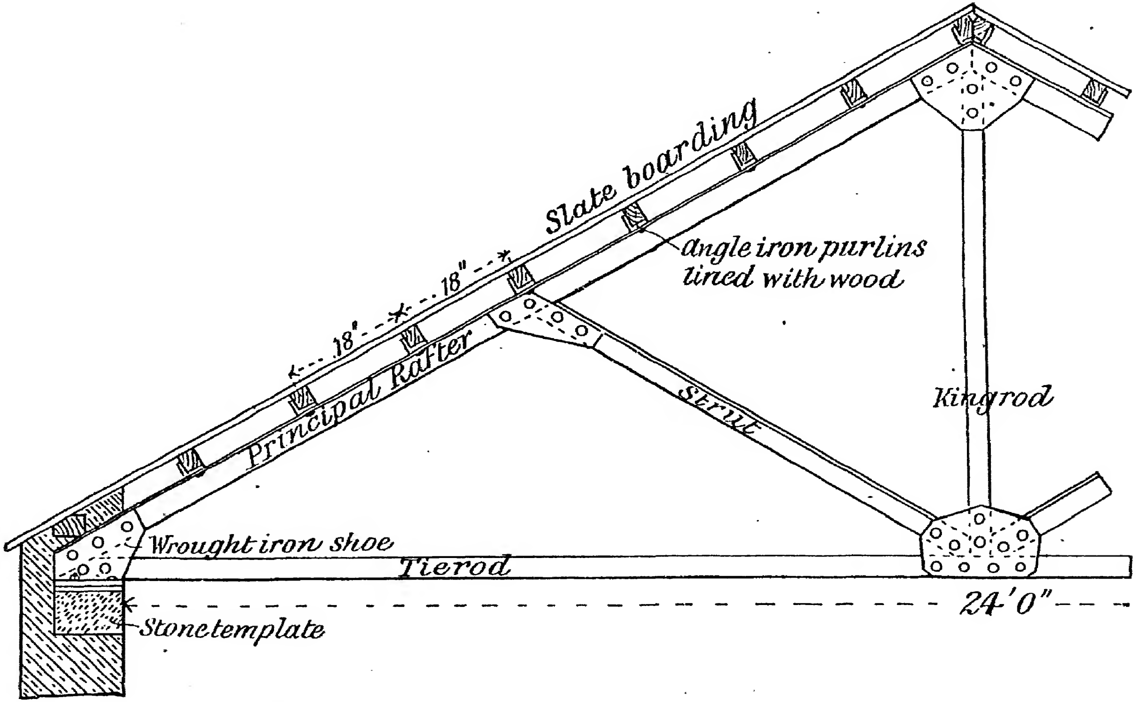


FIG. 340. —Part Elevation of an Iron Roof Truss for a 24' Span.

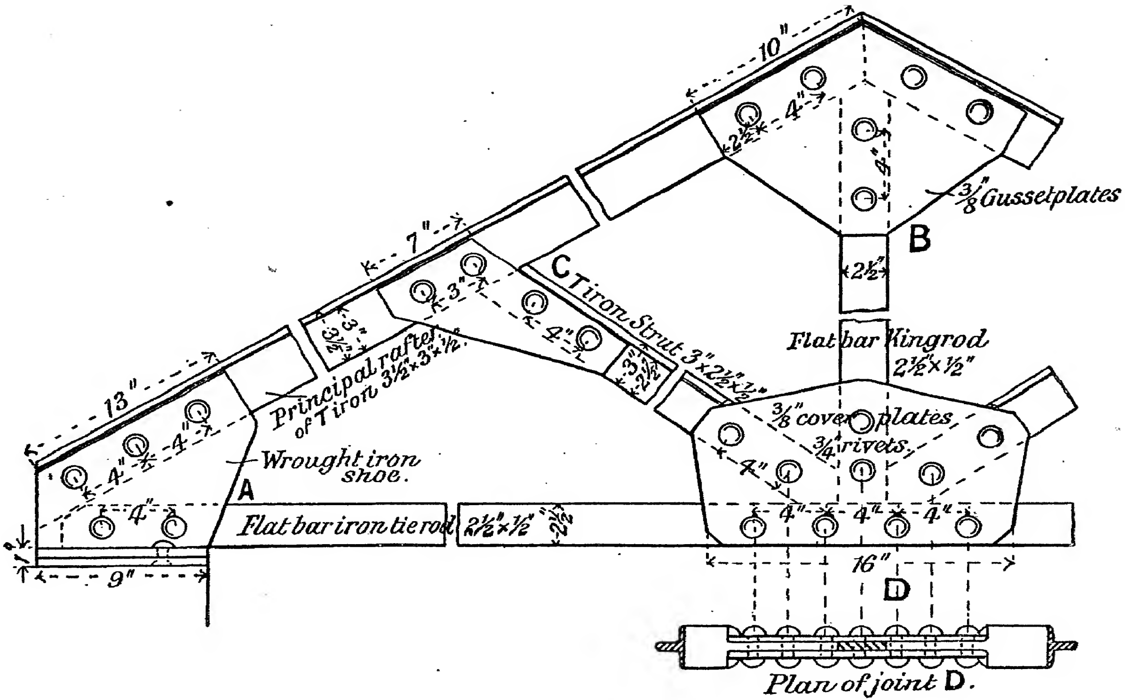


FIG. 341.—Details of Joints of Truss, Fig. 340.

strength of the rod is not reduced. Such a thread is named a *plus thread*.

Fig. 337 shows the elevation of a little more than one half of a roof truss suitable for a span not exceeding twenty-eight feet (28′). T iron is used for the principal rafters, angle iron for the struts, and round iron for all the other members. Fig. 338 shows enlarged details of the joints of this truss. Fig. 340 is the elevation of a truss for a similar span, with the principal rafters and struts of T iron, and all the other members of flat bar iron. The enlarged details of this truss are shown in Fig. 341.

Joint at Foot of principal Rafter.—This joint may be arranged in various ways. Fig. 338, *A*, shows the elevation, Fig. 339 the horizontal section, and Fig. 342 a sketch of a cast-iron shoe, into a groove of which the principal rafter fits, and on to which the tie rod is forked. Both connections are secured by bolts. Figs. 343 and 344 show alternative methods of forking the tie rod. The latter, instead of being forked, may be flattened as in Figs. 345 and 346, and fit into a slot in the shoe. The flattened tie rod may be fixed either by a bolt or by means of a gib and cotter (p. 100). The tie rod, instead of being secured as described above, may pass through a hole in the shoe, and have its end threaded and fitted with a nut behind the shoe. Fig. 348 is a sketch, and Fig. 347 a side elevation, of such a cast-iron shoe. Again, the shoe may be formed as shown in Fig. 349, where two bent wrought-iron or steel plates, having a space for the web of the principal rafter between them, are riveted to a third or base plate.

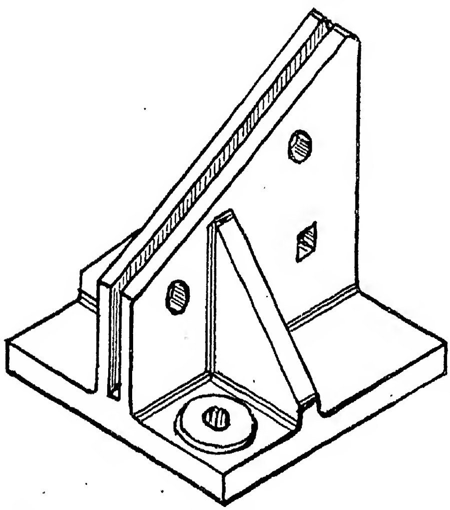


FIG. 342.—Sketch of Cast-iron Shoe at *A*, Fig. 338.

Rag Bolts.—The feet of iron roof-trusses are secured to stone templates by means of rag bolts, known also as *lewis bolts.* A rag bolt differs in shape from an ordinary bolt in having the head end tapering, as shown in Fig. 338, or cut with projecting tongues, as in Fig. 350. It is secured in the stone by means of molten lead or sulphur.

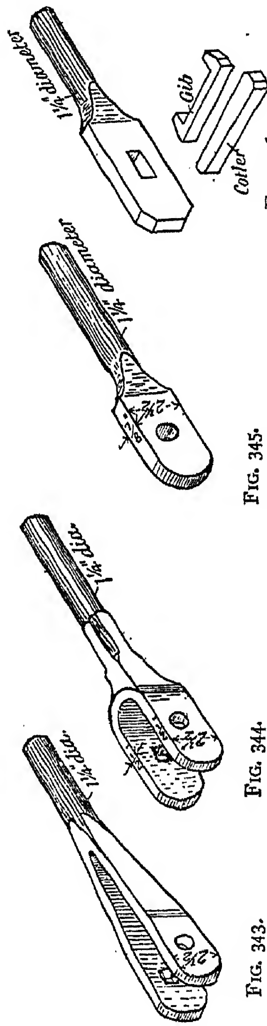


FIG. 346

FIG. 345.

FIG. 344.

FIG. 343.

Alternative methods of forming Ends of Tie and Tension Rods.

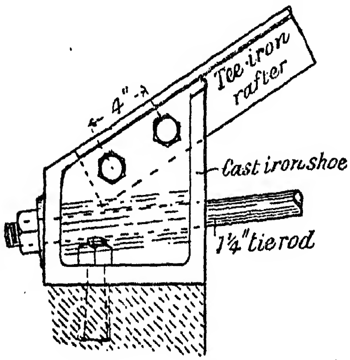
Joint at Head of principal Rafters. — The upper ends of the principal rafters abut against each other, and are connected on each side by means of a wrought-iron plate named a **gusset plate.** The two gusset plates are riveted (as at *B*, in Figs. 338 and 341), or bolted (Figs. 351 and 352) together through the webs of the principal rafters. The tension rods are connected to the gusset plates either by forking on (Fig. 338, *B*), or by having flattened ends which fit between the gusset plates (Figs. 351 and 352). In the latter case thin *packing pieces* are put between the webs of the principal rafters and the gusset plates, to provide room for the flattened ends of the tension rods. Fig. 341 shows the gusset plates used with a flat bar iron King rod, and rivets.

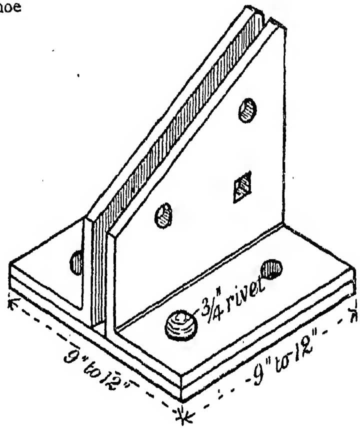
Joint at Head of Strut.—When angle or L iron is used, a simple connection is made by bolting the upper end of the strut to the principal rafter (Fig. 338, *C*). If T iron is used, either part of one side of the flange is cut off to allow the strut to be bolted, as in Figs. 353 and 554, or

wrought-iron plates are bolted or riveted on each side of the web (Figs. 340 and 341, *C*). When a strut is made of channel or flat

FIG. 349.—Sketch of Wrought-iron Connection at foot of P.R.

FIG. 347.—Elevation of Joint at foot of P.R. showing Tie Rod passing through a Cast-iron Shoe and secured with a Nut behind.





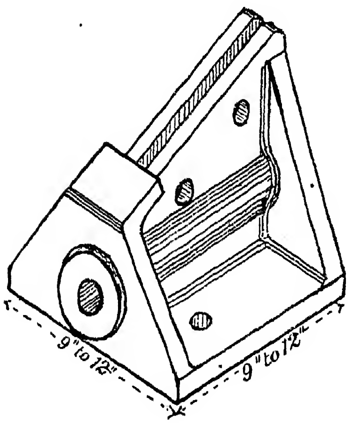


FIG. 348.—Sketch of Cast-iron Shoe of Fig. 347.

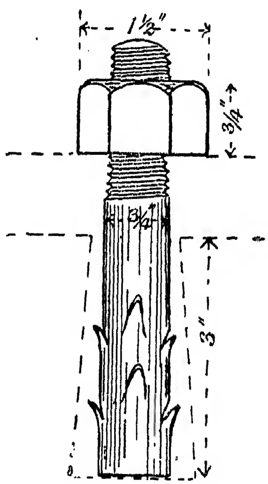
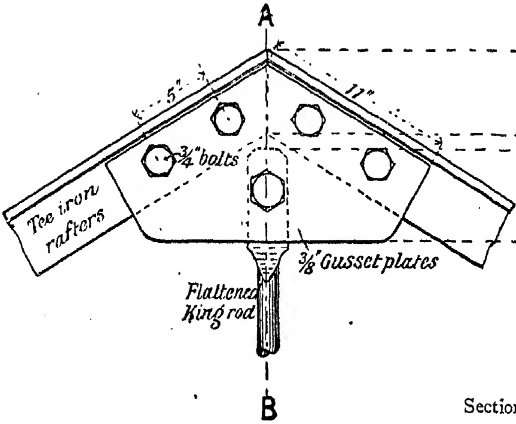


FIG. 350.—Rag Bolt.

bar iron it consists of two pieces, one on each side of the web of the principal rafter, to which latter each piece is fixed by a

bolt passing through the three. In order to further strengthen such a strut, its bars are kept bent outwards by pieces of



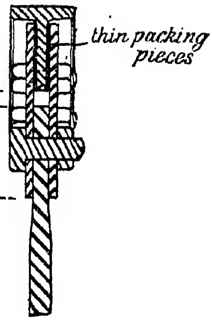


FIG. 352.
Section through AB, Fig. 351.

FIG. 351.—Joint at head of Principal Rafters.

piping inserted between them. Through the pieces of piping rivets are passed. A strut so constructed with flat bar iron is shown in elevation and section in Figs. 360 and 361. When the truss is designed as in the line diagrams, Figs. 323, 325, and 327, the upper end of a tension rod is also fixed at this joint. This method of fixing is shown in detail in Figs. 358 and 359.

Cast-iron Struts are generally of cross-section form, with the ends forked to fit the web of the principal rafter (Figs. 355, 356, and 357).

Joint at Foot of Strut.—Fig. 338, *D*, shows this joint with a flattened continuous tie rod passing between the tension rod and the strut; a bolt goes through all three members to secure the connection. The flattened part of the tie rod is in this case vertical. In Figs. 362 and 363 the flattened part is horizontal, and the lower end of the strut, which is of T iron, is bent and drilled so that the vertical tension rod may pass through both it and the tie rod. The joint requires a nut on each side. Again, the tie rod may be in separate pieces, having one piece forked to receive the other piece and the tension rod. Figs. 364 and 365 show an L iron strut bolted

to the outside of the fork. The strut is of flat bar iron in Figs. 360 and 361.

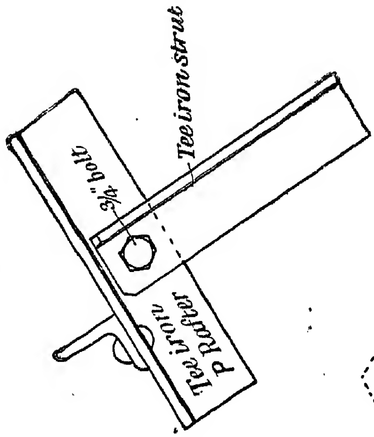


FIG. 353.

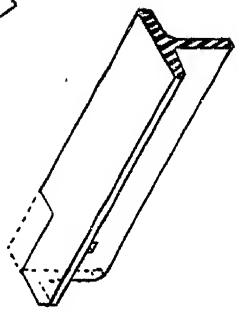


FIG. 354.—Joint at upper end of T iron Strut.

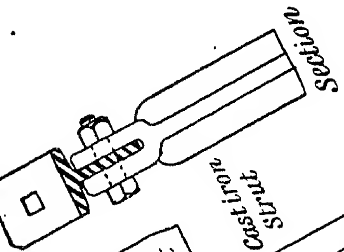


FIG. 356.

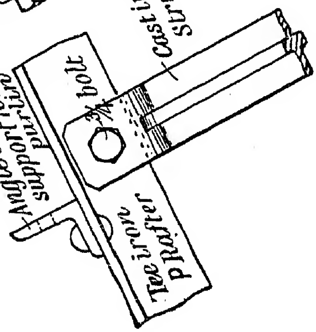


FIG. 355.—Joint at upper end of Cast-iron Strut.

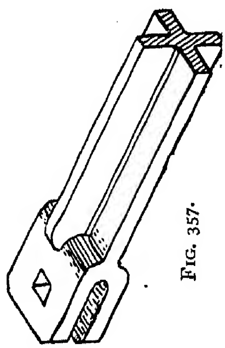


FIG. 357.

Joint at Foot of King Rod.—Figs. 366 and 367 show elevation and plan of the joint at the foot of the King rod suitable for those trusses, the outlines of which are

given in Figs. 321, 323, and 327. The tie rod is in separate pieces, which are connected by means of cover plates and bolts. The struts are of T iron. Fig. 341, *D*, shows the method of constructing the joint with cover plates and rivets.

It is often advisable to connect the different trusses of the same roof by horizontal tie rods, joining the lower ends of the several King rods. The dotted lines in Fig. 367 show the outlines of the larger plates required when such horizontal tie rods are used.

Coupling-joint.—When a truss is completed, it is

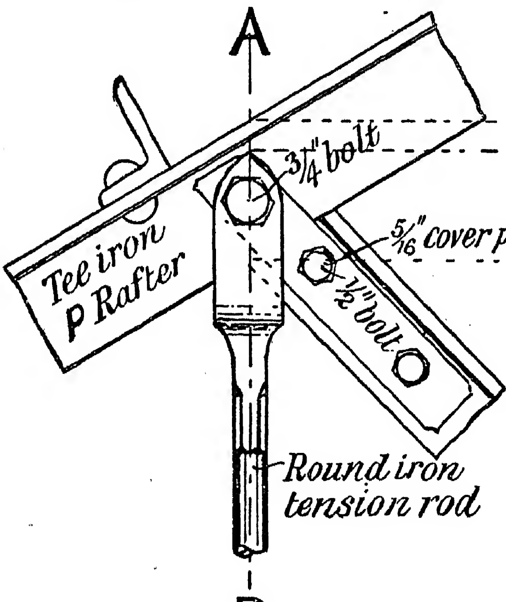


Fig. 358.—Joint at upper end of Strut.

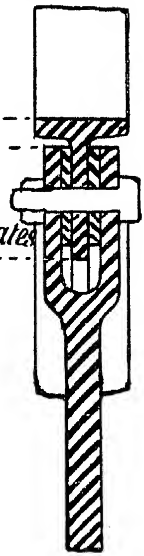


Fig. 359. Section through *AB*.

necessary to tighten up the whole by shortening the tie rod. If the tie rod passes through the shoe, as in Fig. 347, the tightening may be done by screwing up the nut behind the shoe. When, however, the tie rod is fixed to the shoe, a coupling-joint, like that in Fig. 368, may be used. For a coupling-joint of this kind the tie rod must be in separate

pieces, and the threaded ends of the two parts are fitted into the nut. As the thread on one piece is right-handed, and that on the other left-handed, the length of the tie rod is reduced on tightening up the nut.

Purlins.—The foregoing details apply generally to all trusses placed from eight to ten feet (8′ to 10′) apart, and

FIG. 361.

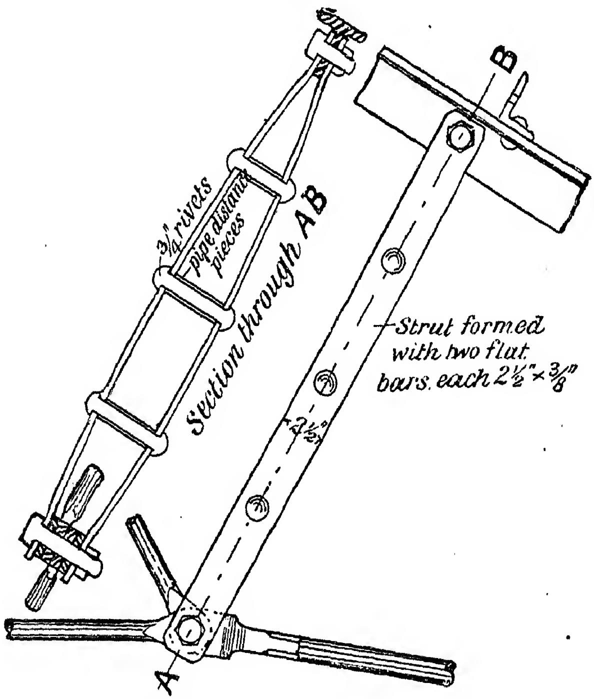
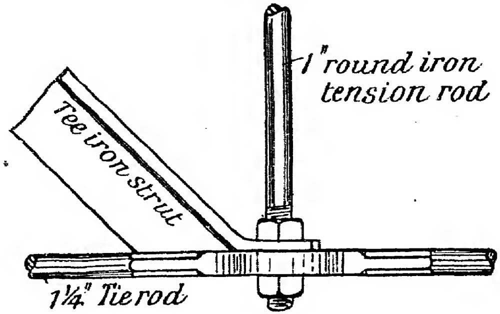


FIG. 360.—Strut formed with two Flat Bars of Wrought Iron.

having heavy wooden purlins supporting common rafters in the manner already described for wooden roofs. Smaller wooden purlins, resting on the tops of the principal rafters, may be substituted when the roof surface is to be boarded. These purlins are placed from eighteen inches to two feet (18″ to 2′) apart, and take the place of the common rafters. When purlins are so arranged the trusses should be placed nearer together, and

FIG 362.



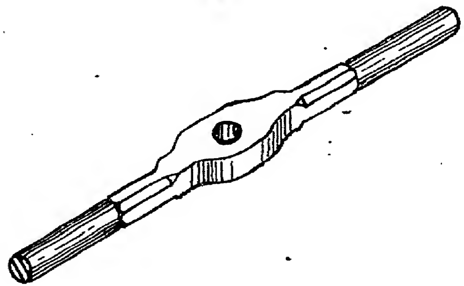
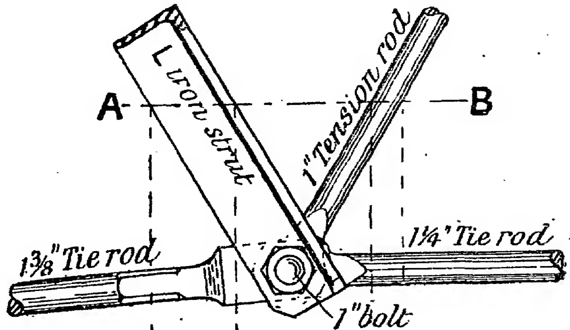


FIG. 363.—Joint at lower end of Strut.

FIG. 364.—Joint at lower end of Strut.



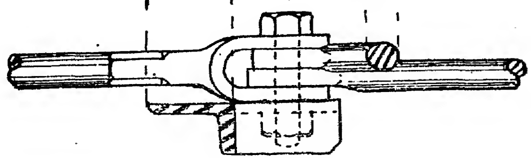
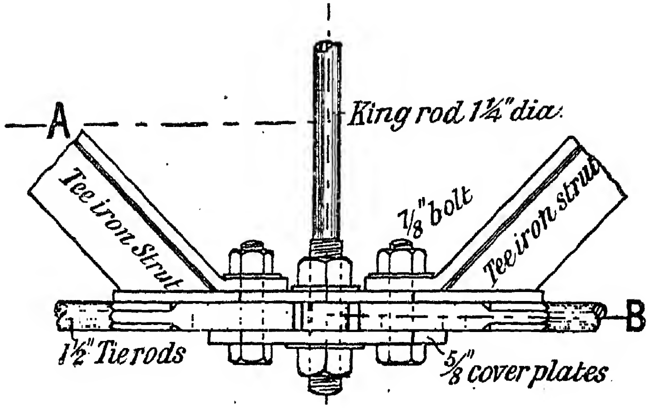


FIG. 365.—Section through AB.

the principal rafters should be made a little stronger, to resist

FIG. 366.—Joint at foot of King Rod.



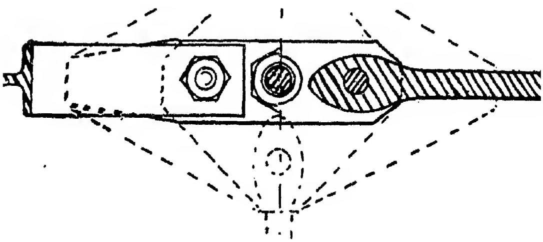


FIG 367.—Section through *AB*.

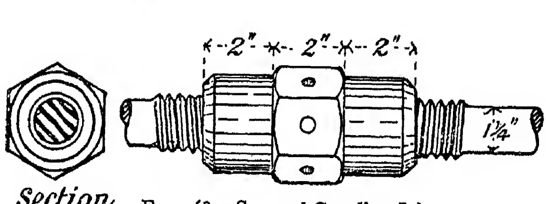


FIG. 368.—Screwed Coupling Joint.

the cross stress put upon them by the distribution of the weight of the roof-covering along their length.

The difficulty of securing common rafters or boarding to *iron purlins* prohibits the general use of the latter, unless they are lined with fillets of wood. Fig. 340 shows angle-iron purlins lined in this manner. Here, also, the roof is boarded. Channel iron may take the place of angle-iron for these purlins.

SUMMARY

Iron roof trusses are made of *wrought-iron* or *steel bars*, with occasional members of cast iron. Such trusses are placed from 8′ to 10′ apart. In general the parts in *compression* are the principal rafters and the struts. The principal rafters are of T iron; wrought-iron struts may be of angle, flat bar, or channel iron; cast-iron struts are of cross section.

The members in *tension* are the tie rod and the tension rods. They are of round or flat bar iron. The tie rod is *cambered* to shorten the struts as much as possible. The feet of trusses are secured to large stone templates in the wall by means of *rag bolts*.

Joints.—Many of the joints are made with *riveted cover plates*. Tie and tension rods are either *forked* to clip the other parts, or are *flattened* at the joints. They are secured with bolts. Means should be provided for tightening up the truss on completion. This can be effected by the use of the *coupling-joint* on the tie rod.

Purlins may be either of the kind used for wooden roofs, or their place may be taken by smaller ones distributed along the length of the rafter. These may be used alone or in conjunction with purlins of angle or channel iron.

QUESTIONS ON IRON ROOF TRUSSES

1. Draw a line diagram of an iron roof truss having a King rod, suitable for a building of 20 feet span, and having walls 14″ thick. Slope of roof, 30°. Scale, $\frac{1}{50}$.

2. Give details of the various joints of the truss of Question 1, the sections of the various members being as follows:—tie rod, $2\frac{1}{2}'' \times \frac{3}{8}''$ flat bar; King rod, $2\frac{1}{2}'' \times \frac{3}{8}''$ flat bar; principal rafters, $3'' \times 3'' \times \frac{3}{8}''$ T iron; struts, $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$ T iron, all the joints being connected with $\frac{5}{16}''$ cover-plates and $\frac{5}{8}''$ rivets Scale, $\frac{1}{4}$ full size.

* 3. Fig. 369 is a line diagram of an iron roof truss; draw the same to a scale of 6 feet to an inch.

Draw, to a scale of 2″ to the foot, the details of the various joints from the following data:—principal rafters, $3\frac{1}{2}'' \times 3'' \times \frac{1}{2}''$ T iron; tie rod, $1\frac{1}{4}''$ diameter; tension rods, 1″ diameter; struts, $3'' \times 3'' \times \frac{1}{2}''$ angle iron. Cast-iron shoe, with tie rod to fork on at foot of principal rafter,

and wrought-iron gusset plates, with $\frac{3}{4}''$ rivets at heads of principal rafters, as shown in Fig. 338.

* 4. Draw a line elevation of the truss given in outline, showing

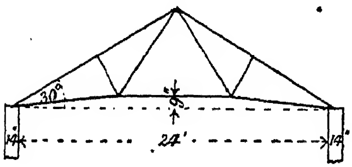


FIG. 369.

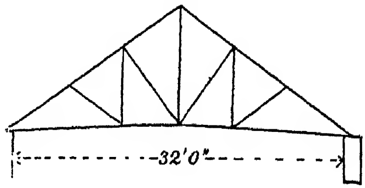


FIG. 370.

the members in tension by single, and those in compression by double, lines (Fig. 370). Pitch of roof, $\frac{1}{3}$. Rise of tie rod, one foot. Scale, $\frac{1}{24}$.

Draw, to a scale of $1\frac{1}{2}''$ to the foot, the details of each of the joints of the truss, having given—principal rafters, $4'' \times 3'' \times \frac{1}{2}''$; tie rod, $1\frac{3}{8}''$ diameter; King rod, $1\frac{1}{8}''$ diameter; tension rods, $\frac{7}{8}''$ diameter; struts, $3'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$ and $2\frac{1}{2}'' \times 2\frac{1}{4}'' \times \frac{3}{8}''$ T iron—the tie rod in two separate lengths, joined in the middle, and passing through a cast-iron shoe at the foot of each principal rafter, and secured with a nut behind.

5. Draw, to a scale of $\frac{1}{2}$ full size, the elevation and section of a screw coupling-joint for tightening the tie rod of a truss, similar in outline to that of Question 3.

EXAMINATION QUESTIONS

* 6. The details of an iron roof truss for a 25-feet span (Fig. 371).

Give, to a scale of $\frac{1}{30}$, an elevation of at least half of the truss.

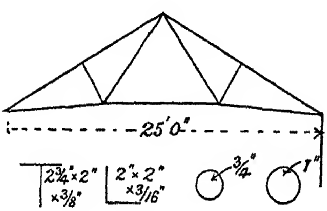


FIG. 371.

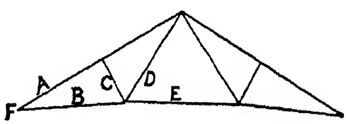


FIG. 372.

7. An iron roof truss over a 24-feet span consists of T-iron principals, $3'' \times 2\frac{1}{2}'' \times \frac{3}{8}''$, two angle-iron struts, $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{3}{8}''$, and five tension rods of $\frac{7}{8}''$ diameter.

Draw the elevation of about half the truss to a scale of two feet to an inch.

8. Draw, to a scale of $\frac{1}{48}$, an elevation of a little more than half of an iron roof truss for a 30′ span, the rise being $\frac{1}{4}$ the span, from the following data:—principal T-iron rafters, $4'' \times 3'' \times \frac{3}{8}''$; three vertical rods of $\frac{3}{4}''$ and $\frac{1}{2}''$ metal; four inclined angle-iron struts, $2'' \times 2'' \times \frac{3}{8}''$ and $2\frac{1}{4}'' \times 2\frac{1}{4}'' \times \frac{3}{8}''$. Tie rod 1″ diameter, with a 9″ camber.

* 9. A line diagram of an iron roof truss for a 25-feet span (Fig. 372).

Show what forms of section you would adopt for each of the members *A*, *B*, *C*, *D*, *E*. Assuming the dimensions of *A* and *B*, give a detail drawing, $\frac{1}{3}$ full size, of the joint *F*, using a cast-iron shoe to form the connection.

* 10. Elevation of one end of an iron roof truss resting on a brick wall, the principal rafter being $4\frac{1}{2}'' \times 3\frac{1}{2}''$, and the tie rod $1\frac{1}{4}''$ (Fig. 373).

Draw, to a scale of $1\frac{1}{2}''$ to a foot, adding a cast-iron shoe bolted down to a 6″ stone template.

The tie rod to be adjusted by a screw nut at back of shoe.

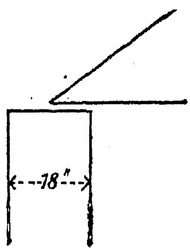


FIG. 373.

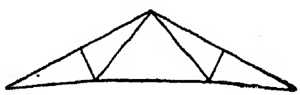


FIG. 374.

* 11. Line diagram of an iron roof truss (Fig. 374).

Draw, $\frac{1}{3}$ full size, an elevation of the joint at the head of the truss, the members consisting of T irons, $2\frac{3}{4}'' \times 2\frac{1}{2}'' \times \frac{1}{2}''$, and bars, $2\frac{1}{4}'' \times \frac{1}{4}''$.

12. Draw, $\frac{1}{4}$ full size, an elevation of the joint at the head of a King rod in an iron roof truss, from the following details:—

King rod, $\frac{3}{4}''$ diameter;
Rafters of T iron, $2\frac{1}{2}'' \times 3'' \times \frac{3}{8}''$;
Slope of roof, 30°.

* 13. Elevation of part of an iron roof truss (Fig. 375).

Draw, to a scale of 3″ to a foot, elevations of the joints at *A* and *B*, the different members consisting of T irons, $3\frac{1}{2}'' \times 3'' \times \frac{1}{2}''$ and $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{5}{8}''$, and $1\frac{1}{8}''$ round iron,

* 14. Line diagram of an iron roof truss (Fig. 376).

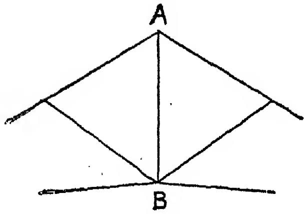


FIG. 375.

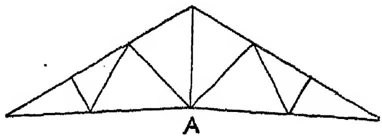


FIG. 376.

Give, to a scale of $\frac{1}{3}$, a detailed drawing of the joint at *A*, the struts being of angle iron, $3'' \times 3'' \times \frac{5}{8}''$, the tie rod $1''$ diameter, and the King rod $\frac{3}{4}''$ diameter.

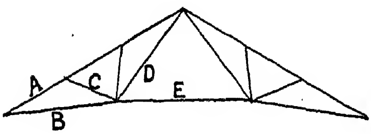


FIG. 377.

15. The King trusses of an iron roof are constructed of the following sections:—

$\frac{5}{8}$-inch and 1-inch round iron ·
$4'' \times 3'' \times \frac{1}{4}''$ T iron ;
$2'' \times 2'' \times \frac{1}{4}''$ angle iron.

Give an elevation, $\frac{1}{2}$ full size, of the joint at the foot of the King rod and at the head of a strut.

* 16. A line diagram of an iron roof truss for a 35′ span (Fig. 377). Show, by sketches, the form of section you would adopt for each of the members marked *A*, *B*, *C*, *D*, *E*.

Assuming the dimensions of *A* and *B*, give a drawing, $\frac{1}{3}$ full size, of the joint connecting them, showing a cast-iron shoe, and some means of tightening up *B*.

* 17. Line diagram of an iron roof truss (Fig. 378).

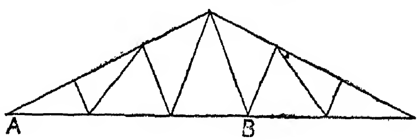


FIG. 378.

Show, by sketches, the sections you would adopt for the different members, and give full details of the joint you would use at *A* and *B*.

CHAPTER IX

SLATING

Battens.—When used as a roof covering slates may either be laid on boards which cover the whole surface of the roof, or they may be carried by narrow wooden laths called **battens.** The arrangement of the slates is similar in both cases. When the slates are laid on boards, battens may or may not be also used. Battens vary in size from three inches by one inch ($3'' \times 1''$) for large, to two inches by three-quarters of an inch ($2'' \times \frac{3}{4}''$) for small slates, and are so placed that the upper edge of each course of slates rests on the batten.

Slope of Roof.—The pitch or slope of the roof when covered with slates ought never to be less than twenty-two degrees (22°) to the horizontal, or with a rise in the centre of one-fifth ($\frac{1}{5}$) the span. But it can only be as low as this when large slates are used. More common inclinations are twenty-six and a half degrees ($26\frac{1}{2}^\circ$), or a rise of one-quarter ($\frac{1}{4}$) the span, and thirty-three degrees (33°), or a rise of one-third ($\frac{1}{3}$) the span. The general rule is:—*the greater the inclination of the roof, the smaller the size of the slates which may be used; and the more exposed the situation, the more the slates should overlap each other.*

Arrangement of Slates.—Slates are laid in courses as shown in Fig. 379. The lower ends of the slates should be in horizontal straight lines, while the edge joints in alternate courses should run in straight lines from eaves to ridge, and should be in the centre of the width of the slates in the course next above and below. It is necessary to notice that at every point of the roof there are two thicknesses of slates, and that the lower edge of each course of slates overlaps the

upper edge of the next course but one below, thus giving three thicknesses of slates over the battens.

Methods of securing Slates.—Slates are secured by being nailed to the battens or boards. Two nails, which may be of copper, zinc, galvanised iron, or composition, are used for each slate. The two methods of nailing slates are as follows :—

Nailing near the centre, or **Centre-nailing**, is the best

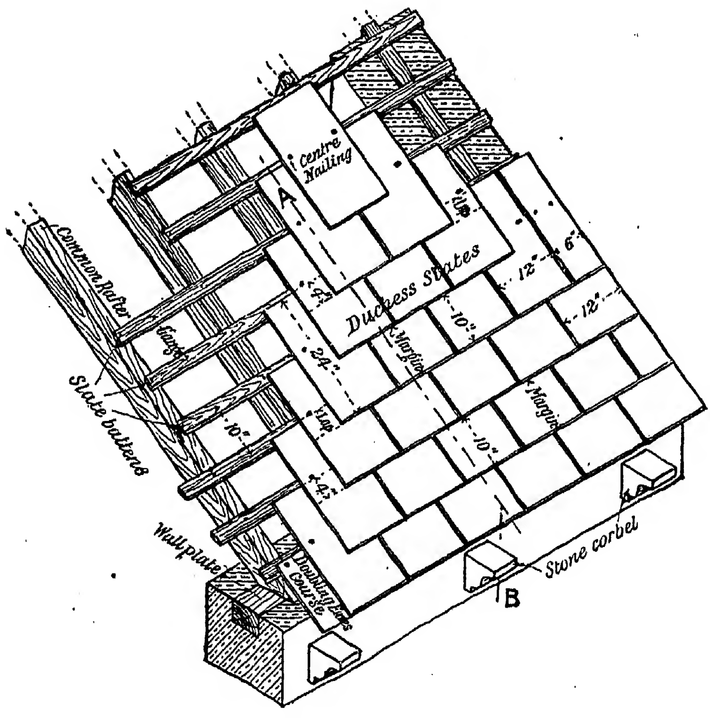


FIG. 379.—Duchess Slating, Centre-nailed, and laid on Battens to 4″ Lap.

method, and the one most frequently used. The nails which secure each course of slates must, when this plan is adopted, be driven into the batten, on which the upper edge of the next lower course rests. The advantage of this method is that the slates, being nailed near the centre of their length, are firmly held in position.

Nailing near the head, or Head-nailing.—The nails are in this method placed about one inch (1″) from the upper end of each slate, as shown in Fig. 384. An advantage claimed for this system of nailing is that the nail-holes are covered with two thicknesses of slates. There is therefore not the same danger, as with centre-nailing, of water getting through the nail-holes. A disadvantage of the plan is that when the slates are nailed near the upper ends the wind acts upon them with great leverage, and in exposed situations is, in stormy weather, liable to strip the roof.

Names given to different sizes of Slates.—Slates are named according to their marketable sizes, which vary considerably. The smaller slates are often employed for covering curved surfaces. The sizes mostly used are *Countess*, 20″ × 10″; and *Duchess*, 24″ × 12″. Other sizes have such names as *Doubles*, 13″ × 7″; *Ladies*, 16″ × 8″; *Marchioness*, 22″ × 11″; *Princess*, 24″ × 14″; *Empress*, 26″ × 16″; *Imperial*, 30″ × 24″; *Rags*, 36″ × 24″; *Queens*, 36″ × 24″.

Parts of a Slate.—The slates should have the smooth side, or *bed*, below when fixed in position. The upper surface is named the *back*. The upper end of a slate is named the *head*,

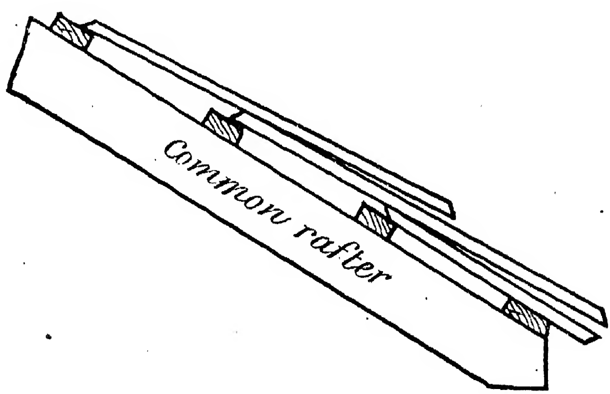


FIG. 380.—Showing effect if Slates were laid without a Tilting Fillet.

the lower end is the *tail*. The *lap* is the distance that the tail of one course of slates overlaps the head of the *next course*

but one below it. The *margin* is the width of the exposed part of each course of slates when in position (Fig. 379). The *gauge* is the distance apart of the laths or battens, measured from centre to centre, and is equal to the margin.

The *eaves* of the roof is the lowest part, and here the slating is commenced. The slates in the lowest or first course laid are shorter than the others by the distance of the gauge. This first course of slates is named the **doubling eaves course**; the slates of this course are laid with their *beds* upwards.

A **Tilting Fillet** is a thicker batten, which is required under the doubling eaves course in order to get the necessary *break* or *tilt* for the slates, as shown in Fig. 384. If this tilting fillet were omitted, the slates would not bed, or lie flat on each other, but would have open joints, as shown in Fig. 380. The tilting fillet is also required where lead gutters are used, as behind chimney-shafts and parapet walls; tilting fillets are also employed against gables, and where valleys are formed, the object being to throw the water away from the joints.

Trimming a Slate.—Slates should always be cut or trimmed with the *bed* uppermost, so that the edge is straight on the smooth side (the bed) of the slate, while the rough side (the back) slopes back or is jagged, as in Fig. 381. This is necessary, since the object of good slating is to have the tails of the slates bedding, or firmly resting, on the course below. There is, in these circumstances, no danger of the wind lifting the slates, or driving the rain under them in stormy weather.

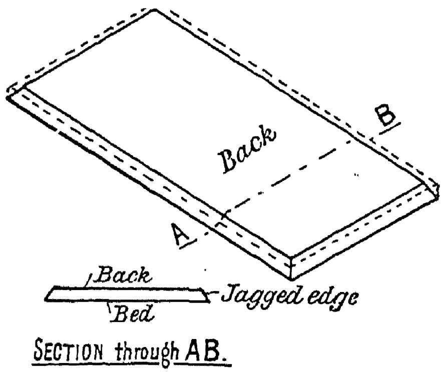


FIG. 381.

Slates should also be sorted into about three thicknesses, the thicker slates being used at the eaves of the roof.

Preliminaries to Slating.—Before commencing slating it is necessary to determine the *gauge*, or the distance from the

centre of one batten to the centre of the next. To do this the amount of lap must be decided upon. The amount of lap is influenced by the situation, the pitch of the roof, and the size of the slates to be used. The lap varies from two and a half to four inches ($2\frac{1}{2}''$ to $4''$). When the slates are centre-nailed, *the gauge is half the difference between the lap and the full length of the slate.*

For example, in *Duchess* slates, where the size is $24'' \times 12''$, what would be the gauge with $4''$ lap?

By the rule given, $\frac{24''-4''}{2} = 10''$ $\therefore$ gauge is $10''$.

Similarly for *Countess* slates ($20'' \times 1{\cdot}0''$) with $3''$ lap, we get $\frac{20''-3''}{2} = 8\frac{1}{2}''$ gauge.

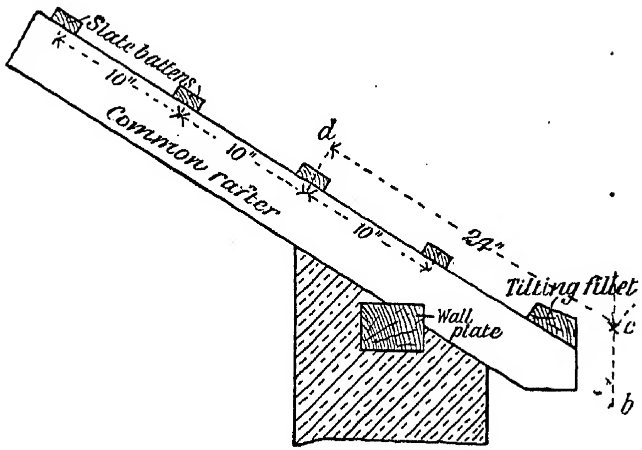


FIG. 382.—Method of drawing a Section through the Eaves of a Slated Roof.

Section through Slating.—An easy method of drawing a section through the slating at the eaves, when the slates rest on battens, is as follows :—Let the slates be *Duchess size*, and the lap $4''$. From the line bc (Fig. 382) to which the slates overhang, measure the length ($24''$) of a slate. The point d is the position of the centre of the batten carrying the head of the *first whole* slate. Draw this batten, and from its centre mark off the gauge ($10''$). One batten is placed with its centre at

this distance (10″) below *d* to carry the heads of the slates of the doubling eaves course. The centres of the remaining battens are marked in the opposite direction at intervals of 10″. In the figure the slates have, for the sake of clearness, been omitted. The positions of the battens having been determined, the slates may be easily drawn in position by proceeding as follows:—Draw the first whole slate in position, leaving room between the bed of this slate and the lower batten for the slate of the doubling eaves course. Draw this slate and the tilting fillet, and then, taking the centre of each batten as the head of a slate, draw the other slates in position. It should be noticed that each overlaps the next but one below by a distance of 4″ (the lap).

Section through the Eaves.—Fig. 383 shows a vertical section through the eaves of a roof on which Duchess slates

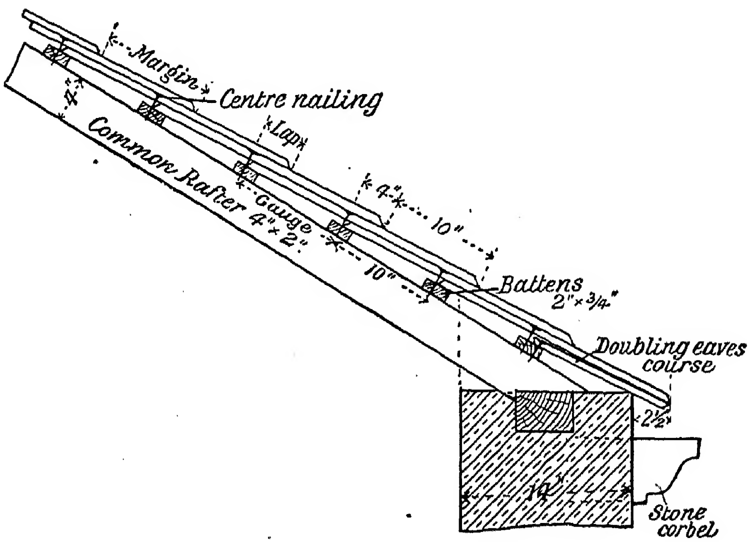


FIG. 383.—Section through *AB*, Fig. 379, showing the Eaves of a Roof covered with Duchess Slates laid on Battens to a 4″ Lap.

with a 4″ lap are laid on battens, and are centre-nailed. The slates overhang the wall just far enough to convey the water into the eaves gutter, which would rest on the corbels. Here

the outer edge of the wall serves the purpose of a tilting fillet. In Fig. 384 Countess slates are laid to a 3″ lap on battens, and are head-nailed. In this case the eaves overhangs the wall, and is finished with a fascia board, to which the eaves gutter is secured. The boarding on the under side—which may either be nailed to the lower sides of the common rafters or be fixed horizontally, as shown by the dotted lines—is named **soffit-boarding.** The distance that the eaves of the roof overhangs the surface of the wall varies from four inches to two feet (4″ to 2′). This method is preferable to having the eaves finished as in Fig. 383, as it affords a means of protecting

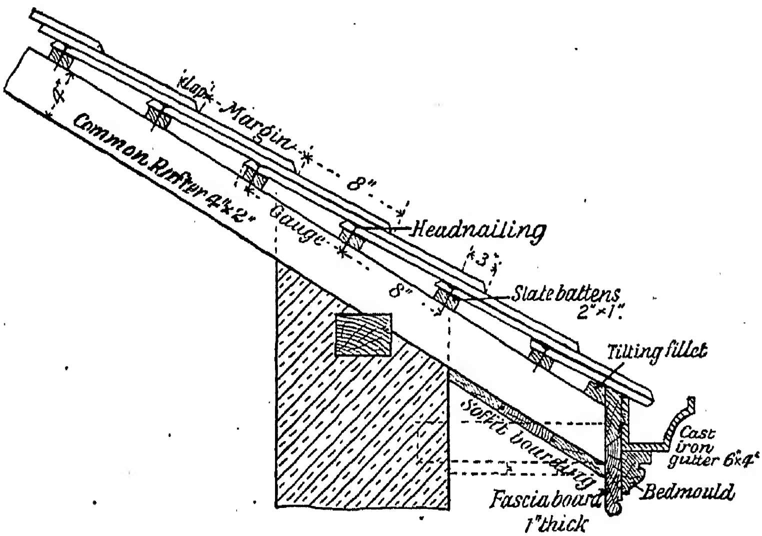


FIG. 384.—Section through the overhanging Eaves of a Roof, showing Countess Slates laid on Battens to a 3″ lap, and nailed at the head.

the walls from the weather. Many other ways of finishing the eaves may be adopted, but the slates in each case overhang the end of the common rafter, the fascia board, wall, or tilting fillet, for a distance of about two and a half inches (2½″) to throw the rain water into the gutter.

Section through Ridge.—The slating near the ridge frequently requires a shorter course of slates to finish with. When this is so a thicker batten is used to obtain the necessary

break or tilt, or the slates will not bed properly. This is shown at *A* in Fig. 385.

In the foregoing remarks it has been assumed that the

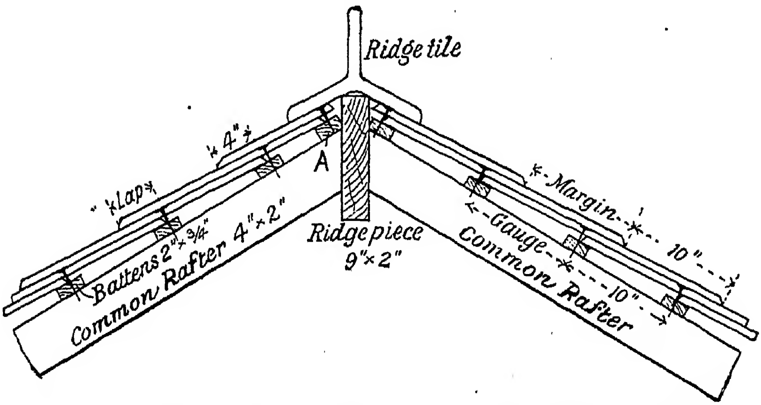
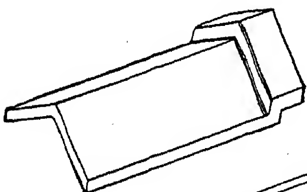
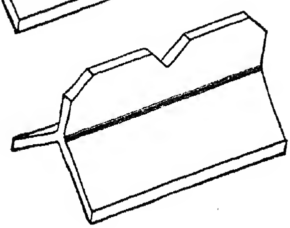


FIG. 385.—Section through the Ridge of a Roof, showing the Slates resting on Battens, and Centre-nailed.

slates are of uniform size. It often happens, however, that a roof surface has to be covered with slates which vary considerably in size. When this is the case the slates are

FIG. 386.





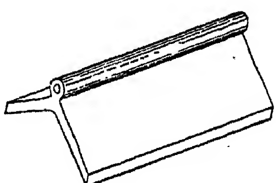


FIG. 387.

FIG. 388.

Sketches of Ridge Tiles.

coursed into varying lengths, and the largest slates are fixed at the eaves. The successive courses are of gradually

diminishing width until the ridge is reached. It is evident that in these circumstances the gauge and margin will both vary.

Ridge Tiles.—The ridge may be finished with tiles of terra-cotta, slate, or with lead ridge rolls (Fig. 403).

Figs. 386, 387, and 388 show ordinary ridge tiles of terra-cotta; these may have rebated (Fig. 386) or butt (Fig. 388) joints. They are bedded on mortar, and pointed with oil-mastic

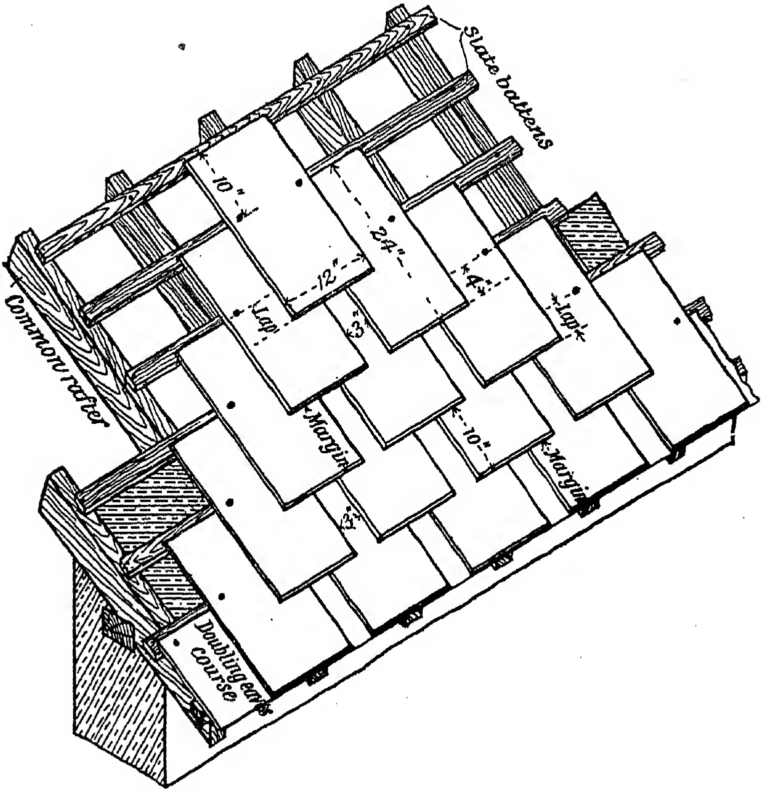


FIG. 389.—Sketch showing Open Slating resting on Battens.

or cement. Slate ridge tiles are generally made in two or more pieces. Lead ridge rolls will be dealt with in a later chapter.

In order to render the slating firmer and more weather-proof, the under sides of the slates are—when laid on battens—either pointed at the joints only (*torched*), or completely

plastered over (*rendered*) with hair mortar. This is done from the inside of the building after the slates are laid in position. When the roof surface is boarded under the slates, these latter frequently have the head ends bedded on mortar for the same purpose.

Open Slating.—For temporary buildings, open sheds, etc., the slates are often laid with a space of from two to three inches (2″ to 3″) between each slate and the next in the same course; this is known as *open slating* (Fig. 389), and effects a considerable saving in the number of slates required.

In slating around hips and valleys, triangular slates of small size are sometimes used. They are secured with one nail only, and often prove a source of annoyance by becoming loose and slipping out of position. It is much better to use larger sized slates.

Summary

Roofing slates are nailed either to *battens* carried by the common rafters, or, better, to *boards* covering the roof surface. They are secured either by *centre-nailing* or by *head-nailing*.

Size.—The commonest sizes of slates are *Countess* and *Duchess*.

The **lap** is the distance which a slate overhangs the next but one beneath it.

The **margin** is the width of the exposed part of each course of slates.

The **gauge** is the distance from the centre of one batten to the centre of the next.

The **doubling eaves course** is the lowest course of slates.

The **tilting fillet** is the thicker batten placed under the doubling eaves course.

A **thicker batten** is sometimes also necessary at the ridge.

Ridge tiles are of terra-cotta or slate, and have rebated or butt joints.

The under surfaces of slates, when laid on battens, are *torched* or *rendered*; if on boards, the slates may be *bedded* on mortar.

Open slating effects a saving of material.

Questions on Slating

1. Draw, to a scale of 1″ to the foot, a vertical cross section through about eight courses at the eaves of a roof having Duchess slates, centre-nailed, laid to a 4″ lap on $2\frac{1}{2}'' \times \frac{3}{4}''$ battens, and carried on $4'' \times 2''$

common rafters, which overhang a 14″ wall for a distance of 12″. Slope of roof, 30°.

Project from this section a plan of the slating, incomplete, so as to show the common rafters (12″ apart), slate battens, etc.

2. A slated roof, with a rise equal to $\frac{1}{3}$ the span, is covered with Countess slates, centre-nailed to $2'' \times \frac{3}{4}''$ battens, and laid to a 3″ lap. The eaves overhangs the wall for a distance of 9″, and is finished with a $9'' \times 1\frac{1}{4}''$ fascia board and cast-iron ogee gutter. The roof, which slopes both ways, has the ridge finished with lapped ridge tiles.

Draw a cross section through about six courses at the eaves, and through three courses on each side of the ridge, showing the slating, and also common rafters, $4\frac{1}{2}'' \times 2''$; ridge piece, $9'' \times 2''$; wall-plate, $4\frac{1}{2}'' \times 3''$; and wall, 18″ thick. Scale, $1\frac{1}{2}''$ to the foot.

Examination Questions

*3. Section through the eaves of a roof (Fig. 390).

Draw, to a scale of $\frac{1}{12}$, adding three courses of slates 20″ long, properly laid to a 4″ lap. Write their names against the different members.

4. Draw, to a scale of $1\frac{1}{2}''$ to a foot, a section through the eaves of a roof, showing $4\frac{1}{2}'' \times 2''$ rafters, with $3'' \times 1''$ battens carrying 24″ slates.

Show four courses of slates, centre-nailed, and laid to a 4″ lap.

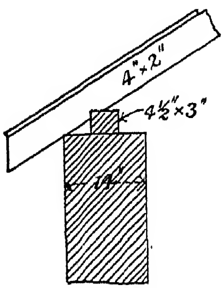


Fig. 390.

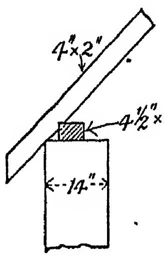


Fig. 391.

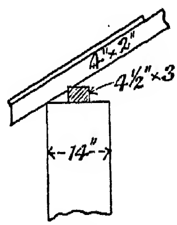


Fig. 392.

*5. Section through the eaves of a roof (Fig. 391).

Draw, to a scale of 1″ to a foot, adding 1″ slate-boarding covered with Countess slates, 20″ × 10″, laid to a 3″ lap, and centre-nailed. The slating to show four margins. The thickness of the slates may be exaggerated to show the details distinctly.

*6. Section of $9'' \times \frac{3}{4}''$ roof-boarding on rafters (Fig. 392). Draw, to a scale of $1''$ to a foot, adding Countess slates, laid to a $4''$ lap, and centre-nailed.

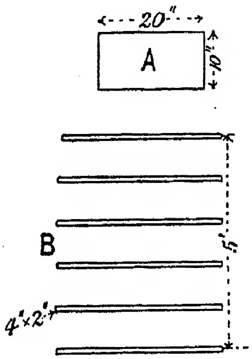


FIG. 393.

*7. *A* is the plan of a roofing slate (Fig. 393).

By what name is this sized slate known?

B is the plan of the ends of six common rafters at the eaves of a roof.

Draw *B*, to a scale of $\frac{1}{2}''$ to a foot, adding $9''$ slate boarding, a tilting fillet and slates, as *A*, laid to a $4''$ lap.

Put five slates in width in the doubling eaves course, and one less in each of the four following courses.

The nail-holes, where exposed, to show centre-nailing.

8. Draw, to a scale of $1''$ to a foot, a vertical cross section through the eaves of a wooden roof, showing the end of the truss carried on a $9''$ wall.

Scantlings as follows:—

Wall-plate, $4\frac{1}{2}'' \times 3''$;
Tie-beam, $10'' \times 5''$;
Principal, $5'' \times 4''$;
Pole-plate, $7'' \times 4''$;
Rafters, $4'' \times 2''$.

Three courses of Countess slates to be shown centre-nailed on $2\frac{3}{4}'' \times \frac{3}{4}''$ battens.

The eaves to be finished with a $4''$ half-round gutter secured to a $\frac{3}{4}''$ deal fascia board.

CHAPTER X

PLUMBERS' WORK

PLUMBERS' work, as far as we are concerned with it in this book, consists in manipulating and laying sheet lead, and in fixing lead pipes, gutters, etc.

Sheet lead is used—

(i.) For making water-tight joints between the walls rising above a roof and the slates abutting against them.
(ii.) For making water-tight joints around chimneys.
(iii.) For forming such gutters as those behind chimneys and parapet walls, and those between sloping roofs, etc.
(iv.) Under certain conditions as a roof covering.
(v.) As a substitute for ridge tiles.

Sheet lead is manufactured in varying thicknesses, and is classed according to its weight per square foot. Thus, "6 lbs. lead" weighs 6 lbs. per square foot. For ordinary work 5 or 6 lbs. lead is generally used; while, for exposed situations, or where it is likely to be much trodden, 7 or 8 lbs. lead is more suitable.

The surfaces on which sheet lead rests are generally boarded, and must be perfectly even, *i.e.* free from sharp corners or "arrises," and properly secured, so that there is no danger of the edges rising (through warping) and damaging the lead. Wherever possible the boarded surface should have the grain of the wood running in the direction in which the current of water over it will flow.

Sheet lead is very much affected by varying states of temperature, expanding in hot and contracting in cold weather. The result is that unless provision be made for these alterations of size—by regulating the size of the sheets and by the arrangement of the joints—the lead will buckle up or tear.

Size of Sheets.—No sheet of lead of greater length than ten feet (10′), or of greater width than three feet (3′), should be used. For flat roof surfaces covered with lead, for gutters, and, in fact, wherever the sheets are arranged lengthwise, it is necessary to have a **fall** or slope, to enable the water to run off. This fall must be at least one inch in seven feet (1″ in 7′), while a still greater fall is an advantage. Soldering, or otherwise rigidly connecting the sheets together, ought always to be avoided, as large sheets, the risks of using which have already been pointed out, are thus obtained.

Joints.—The joints in lead-work must all be arranged in such a manner that no water can pass through them, nor the wind blow under the lead and so force it up. Yet, as before pointed out, the joints must be free enough to allow for expansion and contraction produced by changes of temperature.

Lapped Joints.—Where the fall is not less than one inch in six inches (1″ in 6″), the joints across the water current may be satisfactorily formed by allowing each sheet to overlap the next below it for at least four inches (4″).

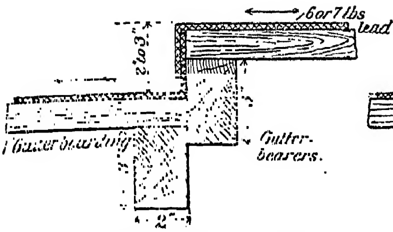
Drips. — In gutters, lead flats, and always where the surface is nearly horizontal and the length to be covered exceeds ten feet (10′), a vertical **step** is necessary wherever two sheets are connected. Such steppings are called **drips.**

The lower sheet is first laid and dressed up against the stepping (which should never be less than 2″ high); the upper sheet is then laid to overlap the lower one. Fig. 394 shows the simplest form of such a drip.

In order to prevent water being drawn up between the sheets by capillary attraction, the upper sheet is not allowed to reach to the bottom of the drip. In the alternative method shown in Fig. 395, capillary attraction is guarded against by the groove. Fig. 396 is a simple modification of the drip shown in Fig. 394, and represents a form known as a *bottle-nose drip.*

Rolls.—Rolls are used—

Fig. 394.



Section through a lead drip.

Fig. 395.

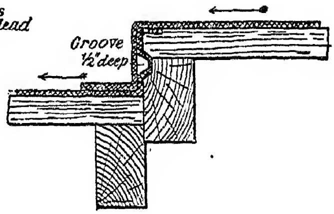
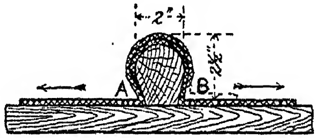
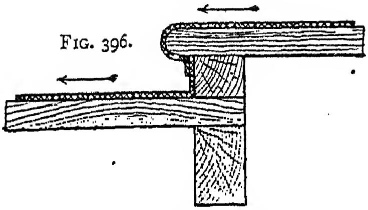


Fig. 397.

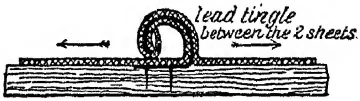


Section through a lead roll

Fig. 396.



Bottle nose drip.



Section through a hollow roll

Fig. 398.

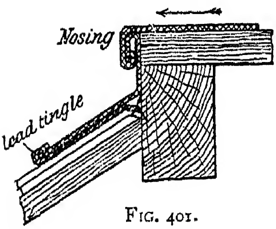
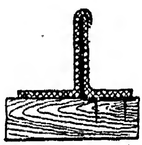


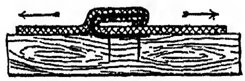
Fig. 401.

Section through a Lead Nosing.



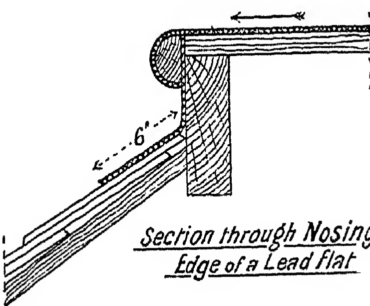
Method of folding lead for hollow roll or seam

Fig. 399.



Section through a

Fig. 400.



Section through Nosing at th
Edge of a Lead Flat

Fig. 402.

(i.) For connecting the joints between the *edges* of the sheets on a lead flat;
(ii.) At the *ends* of sheets at the highest part of a gutter when the flow is both ways;
(iii.) For covering ridges, hips, etc.

Wooden rolls of horse-shoe shape, around which the lead is dressed, are frequently used. Care must be taken to work the lead well into all angles, as those at *A*, *B*, Fig. 397. The outer sheet is often continued in the manner shown by the dotted lines at *B*, though it is doubtful whether any advantage is obtained by doing this; for, if the roll is in an exposed situation the flat part is liable to be blown up, and moisture may then be drawn under the lead by capillary attraction. When one side of a roll is more exposed than the other, the upper sheet should be dressed over on the less exposed side.

Hollow Rolls.—In hollow rolls, which are sometimes used, there is no wooden core. The two sheets of lead are folded over each other as shown in Fig. 398. Strips of stout lead are often fixed between the two sheets at intervals of about two and a half feet ($2\frac{1}{2}'$). Such strips are called **tingles**. They are from two to three inches ($2''$ to $3''$) wide, are nailed to the boarding, and so help to hold the lead in position.

Seams.—Seams are in some cases employed instead of rolls, especially on vertical surfaces. These seams are made in a similar manner to hollow rolls, excepting that they are dressed flat as shown in Fig. 400. Fig. 399 shows the lead turned up ready for folding into the form of a hollow roll or seam. For lead flats and gutters seams are inferior to rolls.

Nosings.—The projecting part of a flat roof which overhangs a sloping roof, or that of a sloping roof overhanging one of greater inclination, is called a **nosing**. Figs. 401 and 402 are sections showing two different arrangements of the lead-work, so arranged as to make such nosings.

Ridge Rolls.—A ridge roll requires a wooden roll to be fixed to the ridge piece. This is effected either by resting the wooden roll on the ridge piece and nailing it, or by employing double-pointed nails as shown in Figs. 403 and 404. The lead, which must be of sufficient width to overhang the slates on each side, is dressed round the wooden roll. Being exposed to the wind, ridge rolls should be formed out of 6 or 7 lbs.

FIG. 403.

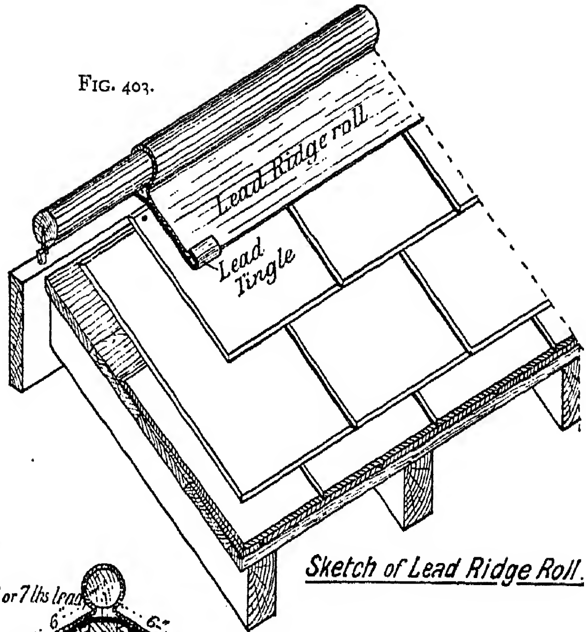
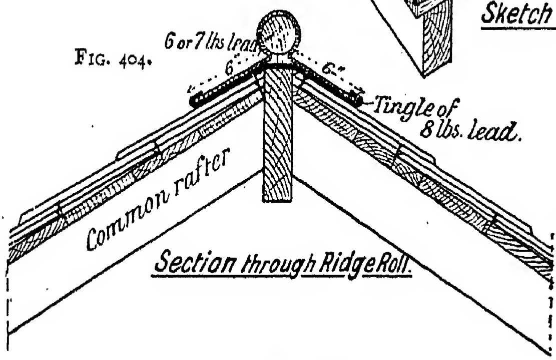


FIG. 404.



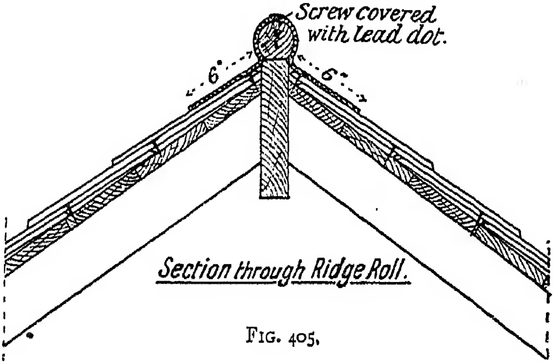


FIG. 405.

lead, and must always be firmly fixed. Fixing by nailing is not advisable, because the alternate expansion and contraction of the lead at length enlarge the nail-holes, and so give rise to leakage. The lead is sometimes, however, secured by screws which pass through galvanised washers and are covered by patches of solder known as **lead dots** (Fig. 405). A still better method is to use "tingles," or strips of stout lead, at intervals of two feet six inches (2′ 6″) apart. These tingles

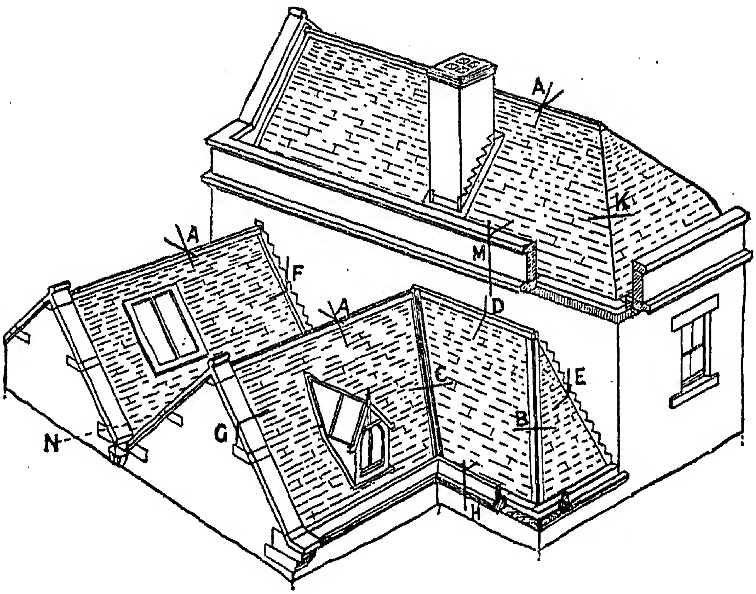


FIG. 406.—Reference Sketch illustrating Plumbers' Work on the Roof of a Building.

are nailed to the ridge piece, passing under the ridge roll, and their lower ends are folded to clip the edges of the lead as shown in Figs. 403 and 404.

Flashings.—Flashings are strips of sheet lead used to render water-tight the various joints that occur between the slating and the walls, chimneys, etc., rising above the roof of a building. These flashings have distinctive names according to the positions in which they are used. An **apron flashing** is such a strip of lead, the upper edge of which is turned for a distance of about an inch and a quarter ($1\frac{1}{4}''$) into a joint in

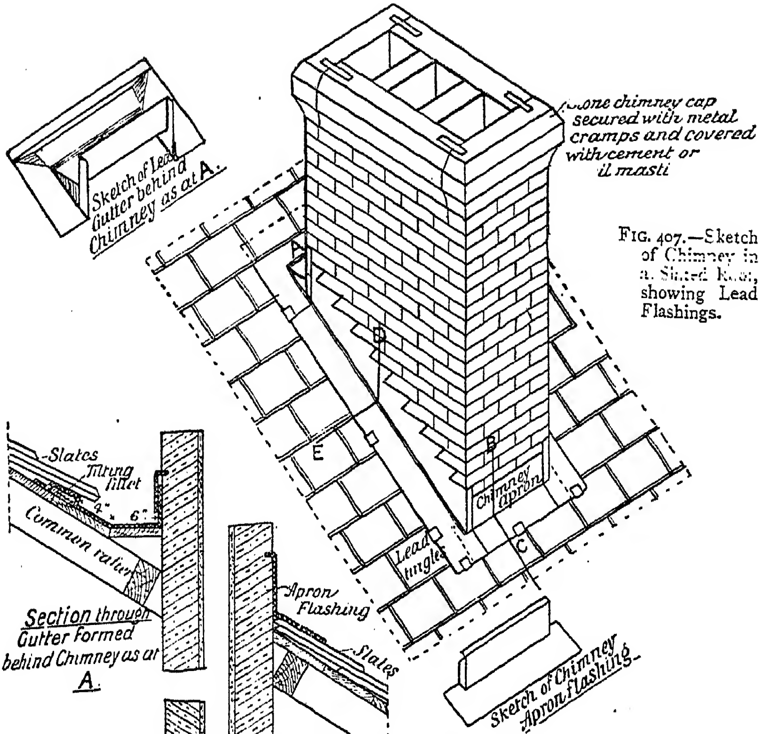


FIG. 407.—Sketch of Chimney in a Slated Roof, showing Lead Flashings.

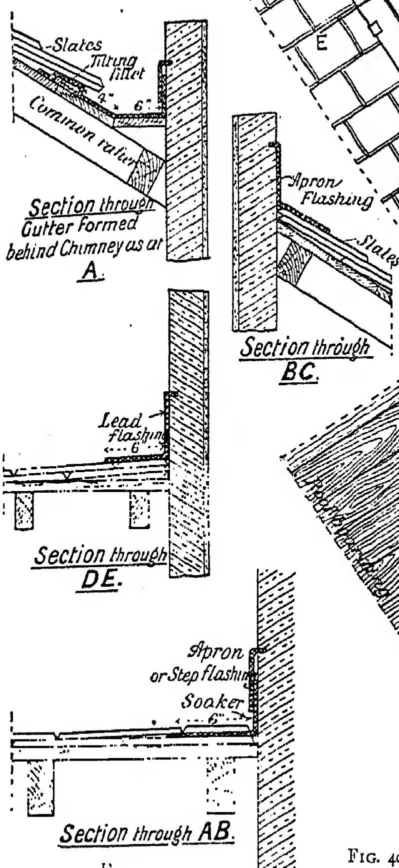


FIG. 409.

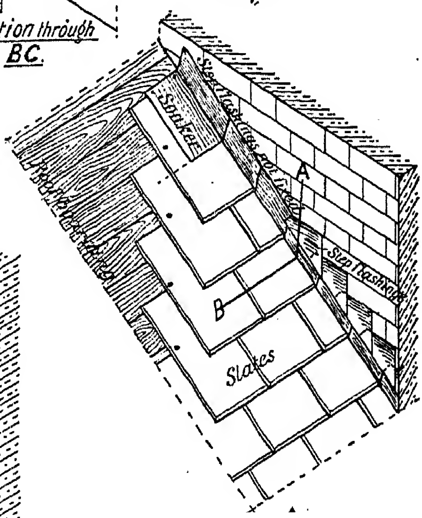


FIG. 408.—Slated Roof against Higher Wall with Lead Soakers and Step Flashings.

the wall, or into a groove named a *raglet*, while its lower edge overhangs the part to be protected.

Chimney Apron.—The flashing between the lower side of a chimney and a sloping roof is generally in one piece. The width required is about sixteen inches (16″). Of this total width, from six to eight inches (6″ to 8″) overlap the slates, about six inches (6″) are turned up against the chimney, and the remainder is turned into a joint in the brickwork of the chimney (Figs. 406 and 407).

Side Flashings.—Where a sloping roof abuts against a gable (*G*, Fig. 406) or higher wall (*E*, *F*, Fig. 406), or against the side of a chimney (Figs. 406 and 407), the flashings are known as *side flashings*, and may be arranged in various ways. Fig. 407 shows the flashing with the lead in one width, turned up L shape, and with the upper edge cut in steps to fit the joints of the brick-work. In cutting the lead, an allowance of about one and a quarter inches ($1\frac{1}{4}$″) is made on the upper edge for turning into the joints of the brick-work. The turned-in edge is secured with lead wedges or wall-hooks. The lower edge rests on the top of the slates, and is held in position by lead tingles nailed to the roof boarding. The width of the lead required is from twelve to fifteen inches (12″ to 15″). The slates in this case are raised, near the wall, by placing a tilting fillet beneath them. The water is by this means thrown away from the wall. In this method the lead is fixed after the slating is finished. An objection to such an arrangement is that in exposed situations the lead is liable to be blown up, and to eventually cause leakage.

Another method, shown in Fig. 411, is to form a gutter by turning up one edge of the lead against the wall and dressing the other edge over a fillet of wood. The upturned edge is overhung by an apron flashing, and the slating is made to overlap the fillet and the other edge. If the slates are laid as shown in section in Fig. 410, so as to hide the gutter (and this is often done), a *secret gutter* is formed.

Soakers.—A third method is to work-in short lengths of sheet lead, named *soakers*, between the slates. The length of the soaker depends upon the size of the slate used. It is made one inch longer than the margin of the slate *plus* the lap. Thus, for Duchess slates, laid with a 4″ lap, the length

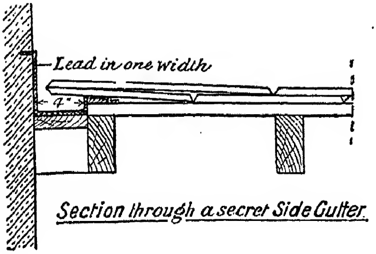


FIG. 410.

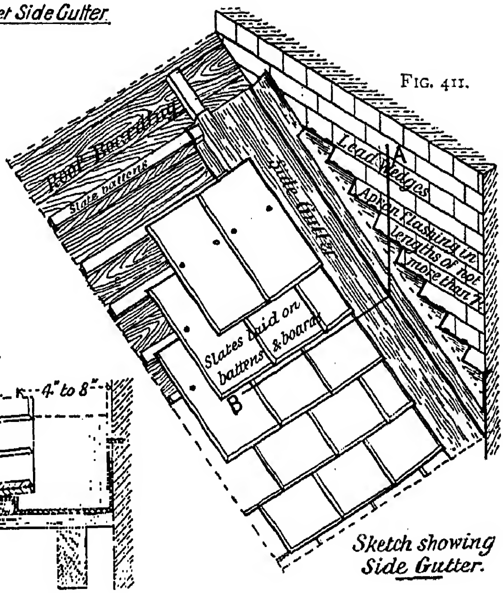
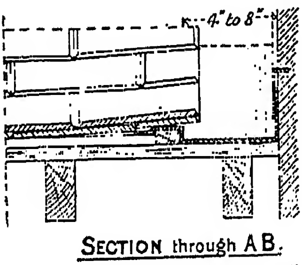


FIG. 411.

FIG. 412.



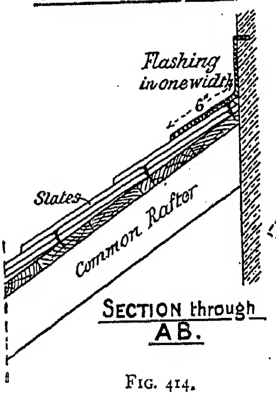


FIG. 414.

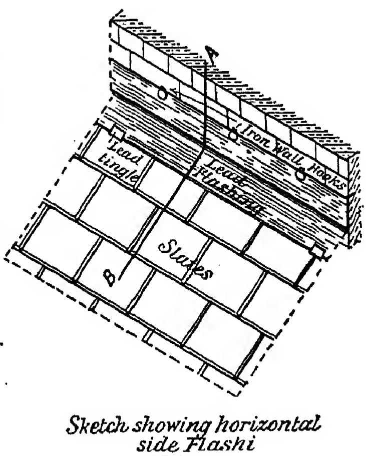


FIG. 413.

of a soaker would require to be equal to the margin (10″) *plus* lap (4″) *plus* one inch, or 15″ long; or, length of soaker = margin of slate + lap + 1″.

The width of each soaker is about ten inches (10″), three or four inches (3″ or 4″) of which are turned up against the wall. Each soaker is secured to the boarding by copper nails as shown in Fig. 408. The apron flashings are in this case often in short lengths, and overlap each other from two to three inches (2″ to 3″), as shown in Figs. 408 and 409.

Step Flashings.—The side flashings shown in Figs. 408 and 411 are also known as *step flashings.*

Raking Flashings.—These are side flashings used in cases where a sloping roof abuts against a higher wall or gable. In raking flashings the groove or raglet into which the lead fits is cut out parallel to the slope of the roof.

Horizontal Flashings.—Horizontal flashings occur along the upper part of a roof abutting against a higher building, as at *D*, Fig. 406. They consist either of—

(i.) One piece of lead from twelve to fifteen inches (12″ to 15″) wide, the upper edge of which is wedged into the joint of brickwork, while the lower edge overhangs the slates and is held by lead tingles as shown in Figs. 413 and 414; or,

(ii.) Two strips of lead: the lower or under flashing being about ten inches (10″) wide, with about four inches (4″) turned up against the wall, the remainder lying on the slates and being held in position with lead tingles. This under flashing is overhung by the upper strip (apron flashing), which may be fixed as described above, or, as is frequently the case, be built into the wall as the work proceeds. When flashings (of whatever kind) are built into the wall, they require to be a little wider than the width given above, since from three to four inches (3″ to 4″) of lead extend into the thickness of the wall.

When flashings are turned into raglets and joints of brickwork or masonry, the joints afterwards require pointing either with cement mortar or with oil mastic.

A Hip, as is shown in Fig. 406, *B*, *K*, is formed where two sloping roofs meet at an *external* inclined angle. The hip at *B*, Fig. 406, is protected by a lead roll. A cross section through this is similar to a section through a ridge roll (Figs. 404 and 405). The upper end of each sheet requires nailing

to the roll to prevent it from slipping down. Such nails should, however, be covered by the overlapping sheet above.

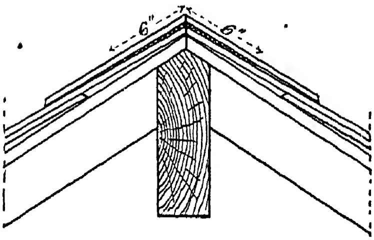


FIG. 415.

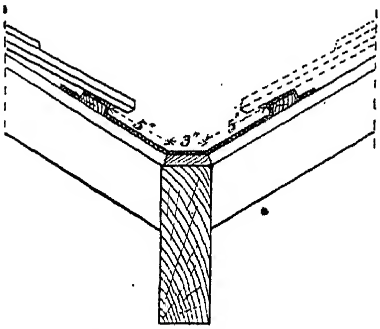


FIG. 416.

A much neater appearance is obtained by the method shown at *K*, Fig. 406, where the slates are cut to fit each other, and have lead soakers worked in with them as shown in section in Fig. 415.

A Valley is formed where two sloping roofs meet at an *internal* inclined angle, as at *C*, Fig. 406. Fig. 416 is an enlarged section through a valley. It will be seen that the lead forms a gutter, and that its edges are dressed over tilting fillets.

Gutters are used—

(i.) Behind parapet walls and stone cornices (Fig. 406, *M* and *H*);

(ii.) Between sloping or M roofs (Fig. 406, *N*);

(iii.) Behind chimneys, etc.

Gutters may be either *parallel* or *tapering*.

Parallel Gutter.—A *parallel*, *box*, or *trough* gutter is of the same width throughout its length, and is formed by fixing a pole-plate (p. 103) at a distance of from nine to thirteen inches (9″ to 13″) from the wall. This pole-plate carries the lower ends of the common rafters. Short pieces of wood, called **gutter bearers**, between the pole-plate and the wall, carry the boarding on which the lead-gutter rests. These

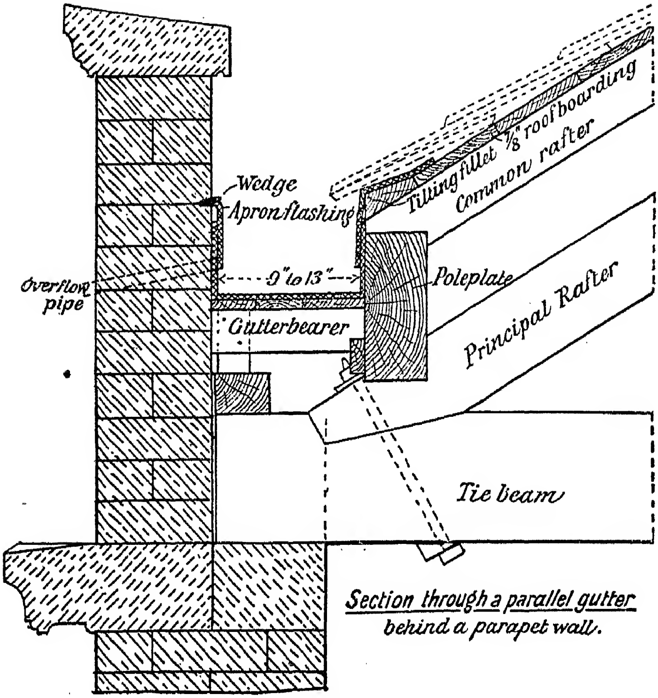


Fig. 417.

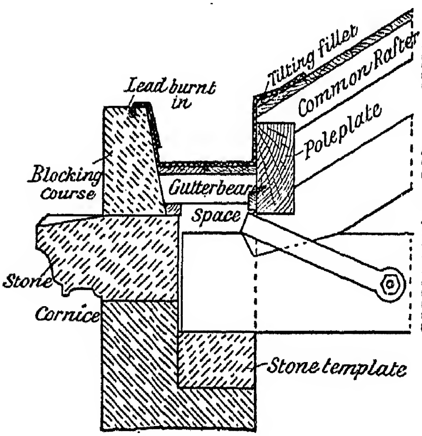


Fig. 418.—Section through a Parallel Gutter behind a Stone Cornice.

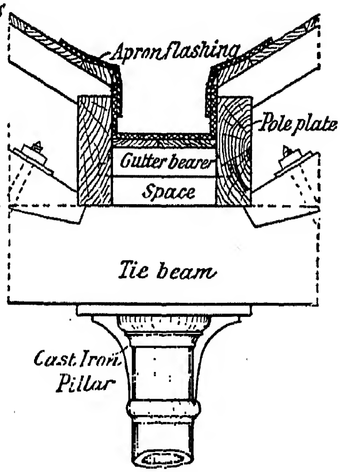


Fig. 419.—Section through a Parallel Gutter between two Sloping Roofs.

gutter-bearers are placed about twelve inches (12″) apart, and must be fixed so that the necessary fall and drips can be obtained when the lead is laid. Fig. 417 is a section through a gutter behind a parapet wall. The lead forming the gutter is turned up at each side, its upturned edges being protected by apron flashings. The apron flashing on the wall side is wedged into a joint of the brick-work, the one on the roof side being dressed over the tilting fillet.

Fig. 418 is a section through a gutter behind a blocking-course (p. 41) which surmounts a stone cornice. In this case the lead which forms the gutter is wide enough to be dressed over the tilting fillet on the roof side. The apron flashing covering the outer edge is fixed into a groove in the top edge of the blocking course. This groove is a little wider at the bottom, and the edge of the apron flashing is "burnt in," as it is called, by running in molten lead. Such a joint holds the apron flashing very firmly if the lead is "caulked," that is, driven well into the groove.

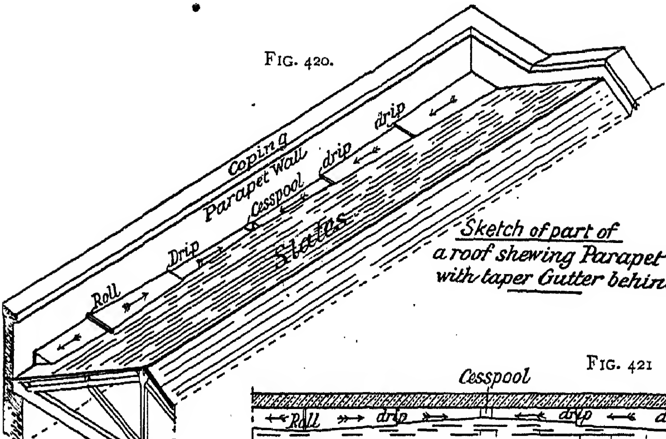
The upper surface of a blocking course is frequently covered with lead as a means of protection from the weather. When the apron flashing serves this purpose, as is often the case, the lead is turned down the front side of the stone for about one inch (1″), and is secured to the stone by **lead dowels.** These are made by pouring molten lead into holes made through the lead and extending into the stone. The exposed end of the lead dowel is formed of a conical shape, like the head of a rivet, as shown in Fig. 428.

A gutter between two sloping or M roofs, such as that at *N*, Fig. 406, is shown in section in Fig. 419. When the gutter is parallel, as is the case in this figure, a pole-plate is required on each side to carry the common rafters. The gutter-bearers are tenoned into the pole-plates.

Tapering Gutters.—A *tapering* or V gutter differs from a parallel gutter in being formed on the top of the common rafters. A pole-plate is therefore unnecessary. Such a gutter is applicable to any place where a parallel gutter can be used. To secure the necessary fall, bearers of gradually increasing length are nailed to the sides of the common rafters. Such a gutter is of necessity widest at its highest point. The shape of the plan of the gutter depends on the slope of the roof and

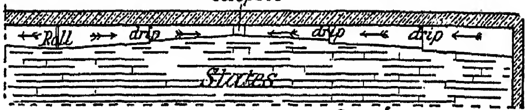
the position of the outlets. The flatter the roof, the wider is

FIG. 420.



Sketch of part of a roof shewing Parapet-Wall with taper Gutter behind.

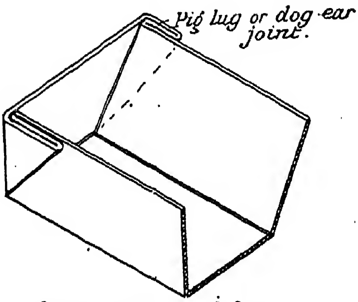
FIG. 421



Plan of taper-Gutter.

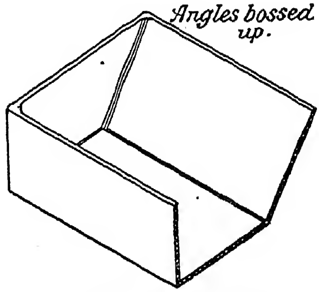
Plan of taper Gutter flowing both ways.

FIG. 422.



Stopped end of lead Gutter

FIG. 423.



Stopped end of lead Gutter.

FIG. 424.

the highest part of the gutter. Fig. 420 is a sketch showing a tapering gutter behind a parapet wall, and Fig. 421 is a plan

of the same gutter. The outlet is in this instance near the middle. The gutter represented in plan in Fig. 422 has an outlet at each end. In the construction of a taper gutter of moderate length, more lead but less timber is required than in a parallel gutter.

Figs. 425, 426, and 427 are cross sections through taper gutters behind a blocking-course, behind a parapet wall, and between sloping roofs respectively. The section in each case is taken near the lowest point of the gutter; the fall, drips, and roll of the higher parts being indicated by horizontal lines. In Fig. 427 the sides of the gutter are not protected by apron flashings, but the edges of the lead are instead turned up and dressed over the tilting fillets. The same method may be adopted in the two other cases, and also in parallel gutters; but as the lead is thus firmly fixed at each side, it is not free to expand and contract with changing temperature, and is therefore liable to tear or bulge.

The stopped ends of a lead gutter may have the lead folded at the corners, as shown by a sketch in Fig. 423, when a **pig-lug** or **dog's-ear** joint is obtained; or the corners may be worked up solid or **bossed up**, as in Fig. 424. The latter process is one of the most difficult operations a plumber has to perform.

Cesspool.—A cesspool is a lead-lined wooden box placed at the lowest part of a gutter. Into it runs the water, to be afterwards conveyed by means of the rain-water pipes to the drains. The outlet at the bottom of the cesspool should have a rose or perforated covering to prevent dirt, dead leaves, etc., from entering and choking the rain-water pipe. Fig. 429 is a sketch, and Fig. 430 is a longitudinal section, of a cesspool.

Overflow Pipes.—To prevent damage being done in case the outlets of lead gutters become blocked, an overflow pipe ought always to be fixed in a prominent position (so that the overflow is sure to be noticed) in all gutters behind parapet walls, etc. This pipe should always be at a lower level than the lowest point of the upturned lead of the gutter (Fig. 417).

Snow Boards.—To prevent the damming-up and consequent leakage resulting from accumulations of snow, dead leaves, etc., in the lead gutters above described, rough frames

of wood are usually laid over them. They also serve to protect the lead.

FIG. 425.

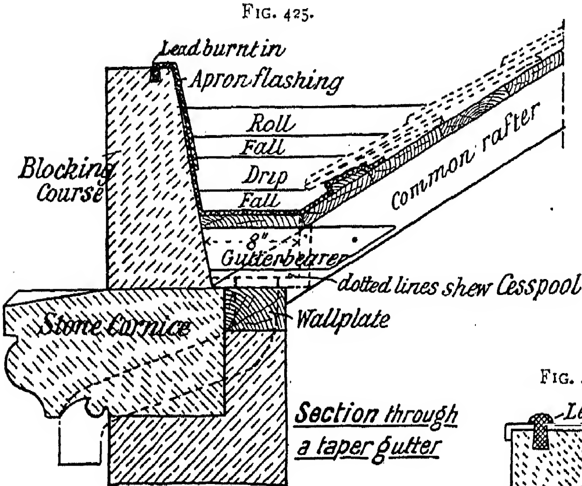
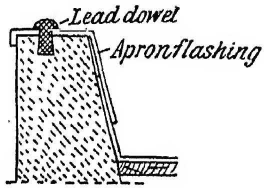


FIG. 428.



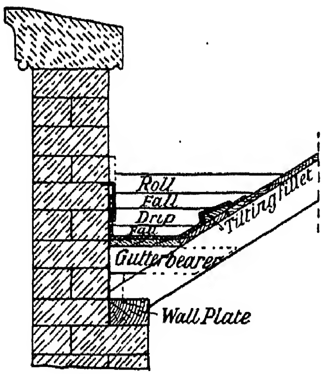


FIG. 426.—Section through a Taper Gutter behind a Parapet Wall.

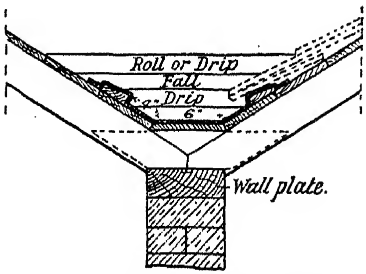


FIG. 427.—Section through a Taper Gutter between two Sloping Roofs.

Cast-iron Gutters.—When the eaves of a roof overhangs the walls, cast-iron gutters are usually employed (Fig. 384). They are prepared by the iron-founder, but are generally fixed by the plumber. They are of varying designs and lengths

(usually six feet). Cast-iron gutters are either secured in position by screws to the fascia boarding, or are carried by

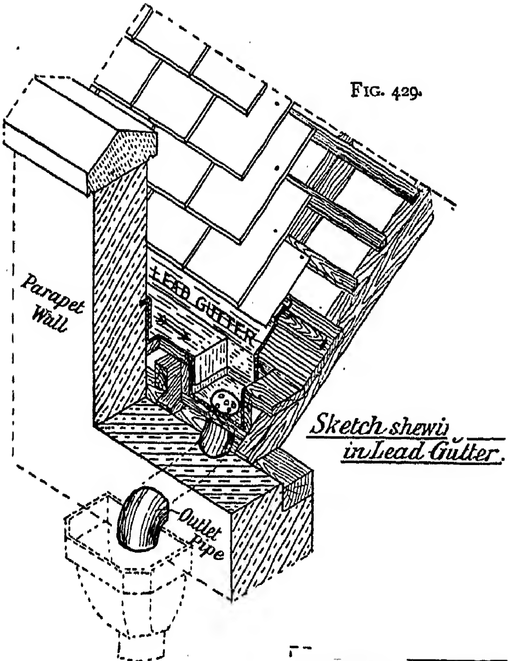


FIG. 429.

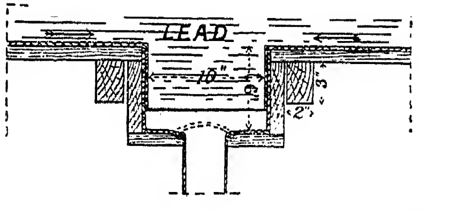


FIG. 430.

wrought-iron gutter-bearers screwed to the common rafters, the joints being formed by small bolts and cement of red and white lead.

Behind parapet walls and between the sloping roofs of mills,

warehouses, workshops, etc., cast-iron gutters of the shapes shown in section in Figs. 431 and 432 are often used. They

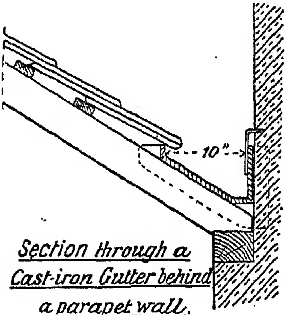


FIG. 431.

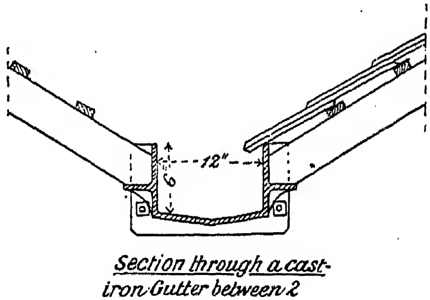


FIG 432.

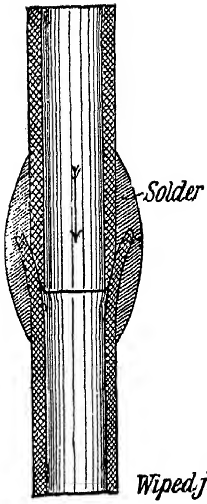
are made in long lengths, and have the advantage of not requiring so great a fall as lead gutters. The joints are made with bolts and a cement obtained by mixing cast-iron borings with sal-ammoniac and water. When such a gutter is used behind a parapet wall, the joint between the wall and the gutter is overhung by a lead apron flashing (Fig. 431).

Fig. 432 shows a section through an iron gutter, between two sloping roofs, which has flanges on the outer sides to carry the lower ends of the common rafters.

Rain-water Pipes.—These are either of lead or cast iron. The former are very expensive, and not often used except in superior work. Cast-iron pipes are circular or rectangular in section, and are secured to the wall either by iron holdfasts which clip the pipe, or by nails passing through projecting "ears," which are cast on the pipes. The usual length is six feet (6′), the upper end having a socket into which the lower end of the pipe next above fits. These pipes are usually surmounted by an enlarged head into which the outlet from the gutter empties, as shown by the dotted lines in Fig. 429.

Lead Dots.—It is often necessary to fix sheet lead in an almost vertical position, as on roof turrets, dormer windows, etc. In this and other cases the sheet lead may be secured to the wood-work by means of screws provided with galvanised washers. The head of the screw is afterwards covered with

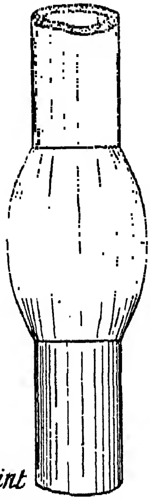
FIG. 433.



Wiped joint

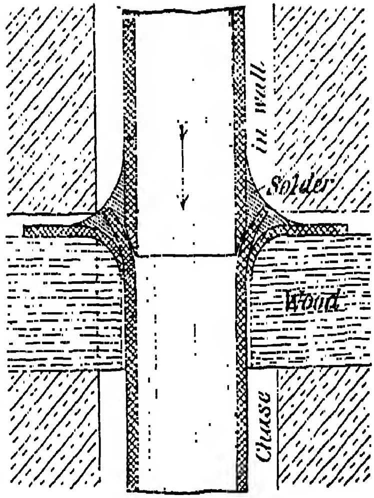
Section.

FIG. 434.

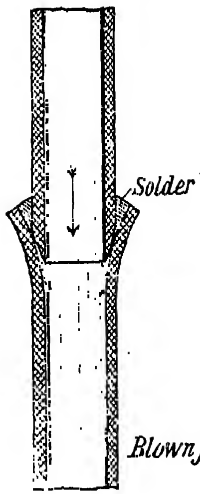


Elevation.

FIG. 437.



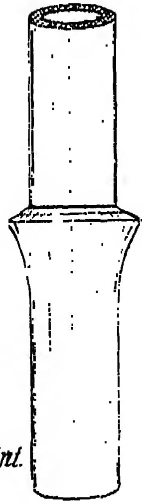
Section.



Blown joint.

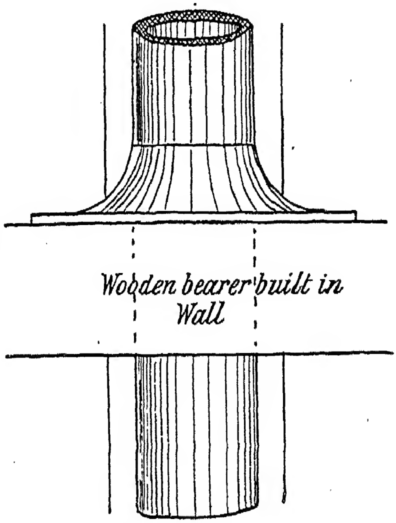
Section.

FIG. 435.



Elevation.

FIG. 436.



Elevation.
Flanged joint.

FIG. 438.

a patch of solder. Such a patch is called a **lead dot.** It is advisable, wherever possible, to first hollow out the boarding in the position of the screw, so that the lead dot may be finished flush with the surface of the lead.

Pipe Joints.—It is part of a plumber's work to arrange and lay water-, gas-, and soil-pipes. The joints of lead pipes conveying water under pressure are generally made as shown in section and elevation in Figs. 433 and 434. This joint is called a **wiped joint.** The direction of the water current is indicated by the arrow. Figs. 435 and 436 show a **blown joint.** A blown joint is suitable for discharging-pipes and for lead and composition gas-pipes. When lead pipes (soil-pipes, for example) are fixed vertically in a groove—called a *chase*—in the wall, the **flange joint** shown in Figs. 437 and 438 is used. It is so constructed that the flange of the joint rests upon the block.

Summary

Sheet lead is used for making water-tight joints on the roofs of buildings, and for gutters. No sheet should be more than ten feet long and three feet wide.

The **joints** used for connecting sheets are *lapped joints*, *drips*, *rolls*, and *seams*.

The different kinds of **flashings** are respectively named *apron* and *side* (*step*, *raking*, or *horizontal*) flashings and *soakers*. They are secured into joints of brick-work or masonry by *lead wedges* or *wall-hooks*.

Tingles are strips of thicker lead used for holding certain flashings, *ridge rolls*, and *hip rolls* in position. The heads of screws used for securing sheet lead to wood-work are protected by **lead dots.**

Gutters are *parallel* or *taper*. They are used behind parapet walls, blocking-courses and chimneys, between sloping roofs, etc. The *fall* of a gutter should be not less than one inch in seven feet, and the drips should be not more than ten feet apart.

A **cesspool** is placed at the lowest part of a gutter.

Overflow pipes should be in conspicuous positions.

Cast-iron gutters are used for *overhanging eaves*, and often also take the place of lead gutters behind parapet walls, etc.

Rain-water pipes are of lead or cast iron.

The **joints of lead pipes** are *wiped*, *blown*, or *flanged*, according to their use and position.

Questions on Plumbers' Work

1. Draw, to a scale of 3″ to the foot, cross sections of—
   (*a*) A $2\frac{1}{2}''$ lead drip, the lead to rest on 1″ gutter-boards carried by $3\frac{1}{2}'' \times 2''$ bearers.
   (*b*) A lead roll with a wooden core $2\frac{1}{2}''$ high and 2″ wide, with gutter-boards and bearers as in (*a*).
   (*c*) A hollow roll 2″ in diameter.

2. Draw, to a scale of 2″ to the foot, the following details of Fig. 406, showing Countess slates laid to a 3″ lap on 1″ slate boarding; and $4'' \times 2\frac{1}{4}''$ common rafters placed 12″ apart:—
   (*a*) Cross section through a ridge—as at *A*—showing a $2\frac{1}{2}''$ lead ridge roll resting on a $9'' \times 2''$ ridge piece.
   (*b*) Cross section through a hip—as at *B*—showing a $2\frac{1}{2}''$ lead roll and a $12'' \times 3''$ hip rafter.
   (*c*) Cross section through a valley—as at *C*—showing the lead gutters 8″ wide, and a $12'' \times 3''$ valley rafter.
   (*d*) Cross section showing the arrangement of the lead flashings at *D*, the lead being in two widths.
   (*e*) Cross section through *E*, showing soakers, and step flashings in short lengths.
   (*f*) Project from (*e*) an elevation, showing the step flashings, and also the slates and roof boarding in section.
   (*g*) Cross section through *F*, showing a 4″ secret side gutter.
   (*h*) Cross section through a gable—as at *G*—showing a 6″ side gutter with the apron flashings in long lengths.
   (*k*) Cross section through a parallel gutter between two sloping roofs—as at *N*—showing $10'' \times 3''$ pole-plates, 1″ gutter-boards, $3'' \times 2''$ gutter bearers, and all plumbers' and slaters' work.

3. A chimney shaft, $3'\ 9'' \times 1'\ 10\frac{1}{2}''$ outside dimensions, penetrates through a slated roof, having the short sides parallel to the ridge. The roof is covered with Duchess slates laid to a 4″ lap on $2\frac{1}{2}'' \times \frac{3}{4}''$ battens and $4'' \times 2\frac{1}{2}''$ common rafters.

Draw cross sections showing the details of the lead-work necessary to make watertight joints between the brick-work of the chimney and the slating.

Draw also an elevation of the wider side of the chimney shaft, showing step flashings in elevation and slates in section.

Scale, $1\frac{1}{2}''$ to the foot.

* 4. A vertical cross section through the eaves of a roof finished with a stone cornice and blocking-course (Fig. 439).

Draw, to a scale of $\frac{1}{8}$ full size, adding all

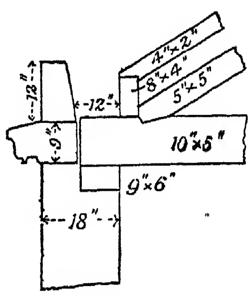


Fig. 439.

necessary details of lead-work and slating, using Countess slates laid to a 3″ lap.

5. Draw a vertical cross section through a tapering lead gutter behind a brick parapet wall, as shown in Fig. 426. Scale, 2″ to the foot.

Examination Questions

6. Give a cross section of a 2″ drip in a lead gutter, half full size, showing 1″ boards and 3″ × 2″ bearers.

7. Draw, to a scale of $\frac{1}{4}$, cross sections of the joints you would use in the lead gutter of a roof to connect the ends of the sheets together.

8. Give sketches explaining the following terms :—

Tilting fillet and doubling eaves course.

Step flashing to brick chimney.

9. Draw, to a scale of $\frac{1}{8}$, a cross section through a lead gutter at the back of a chimney shaft, showing all the details of construction, the rafters being 4″ × 2″, carrying Countess slates (3 courses to be shown) on $\frac{3}{4}$″ boards.

* 10. Elevation of end of brick chimney shaft, with section through part of adjoining roof, showing slate boarding and rafter (Fig. 440).

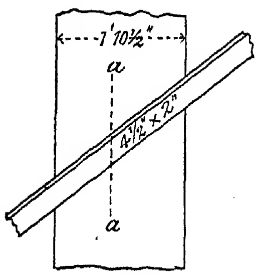


Fig. 440.

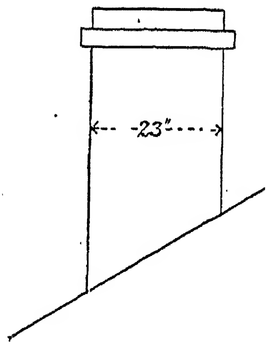


Fig. 441.

Draw to a scale of $1\frac{1}{2}$″ to a foot, adding 20″ Countess slates laid to a 3″ lap, with step flashings, etc., to keep out the weather. Give a section of the same through *a*, *a*.

* 11. Elevation of a brick chimney shaft, rising through a slate roof (Fig. 441).

Draw, to a scale of $\frac{3}{4}$″ to a foot, a cross section through the shaft, showing the details of the lead-work and fixing, including two courses of 18″ slates, both above and below the shaft.

* 12. Section through the gable end of a slate roof, showing a brick parapet with stone coping, common rafters, and slate boarding (Fig. 442).

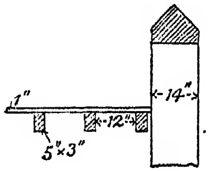


Fig. 442.

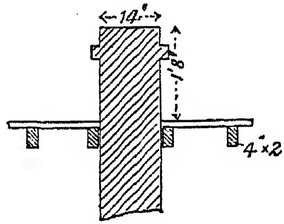


Fig. 443.

Draw, to a scale of $\frac{1}{12}$, adding Countess slates and lead flashing to keep the weather out.

* 13. Section through a portion of a slate roof divided by a party wall (Fig. 443).

Draw, to a scale of $\frac{1}{12}$, showing the slates, with two different methods of using lead to form a water-tight joint between them and the wall. The thickness of the slates should be exaggerated, and the section should pass through a lap.

14. Draw a cross section, to a scale of 1" to a foot, through an 8" lead gutter with step flashings, formed at the end of a boarded and slated roof butting against the brick wall of another building. Also show the step flashings in elevation.

* 15. Cross section through a roof gutter behind a brick parapet (Fig. 444).

Draw, to a scale of $\frac{3}{4}$" to a foot, adding the bricks, slate boarding and tilting fillet, lead gutter and flashing.

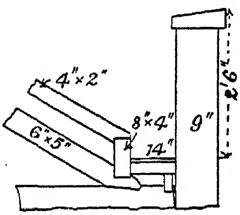


Fig. 444.

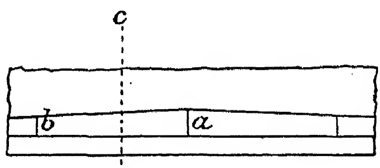


Fig. 445.

* 16. Plan of part of a lead roof gutter behind a brick parapet, showing the position of the joints in the lead (Fig. 445).

Draw, to a scale of $\frac{1}{4}$ full size, cross sections through *a* and *b*, giving full details of the joints. Also draw a section through *c*, *c*, including three courses of Countess slates on 1" boards.

* 17. Section through a gutter at the centre of an M roof (Fig. 446). Draw, to a scale of $1\frac{1}{2}''$ to a foot, adding $\frac{3}{4}''$ slate and gutter boarding,

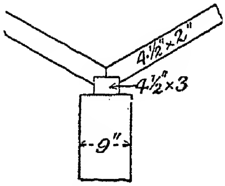


Fig. 446.

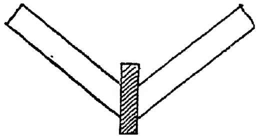


Fig. 447.

and a lead gutter; and, on one side, Countess slates laid to a $4''$ lap.

* 18. Section of a valley in a slate roof (Fig. 447).

Draw correctly, to a scale of $\frac{3}{4}''$ to a foot, giving the details of the lead gutter and slates, at least three courses of Countess slates on one side of gutter.

19. Give a vertical section $\frac{3}{4}$ full size, through a plumber's flange joint in an inch lead pipe passing through a $1\frac{1}{4}''$ floorboard.

CHAPTER XI

DOORS

Doors.—Doors may be either *ledged*, *framed and ledged*, or *framed and panelled.*

Ledged Doors.—Ledged doors are only used for outbuildings and temporary work. They consist of battens or boards securely nailed to cross ledges. Fig. 448 shows the back elevation and vertical section of a typical ledged door. The joints of the battens of which a ledged door is constructed may be either—

(i.) Tongued and grooved;
(ii.) Ploughed and tongued;
(iii.) Rebated.

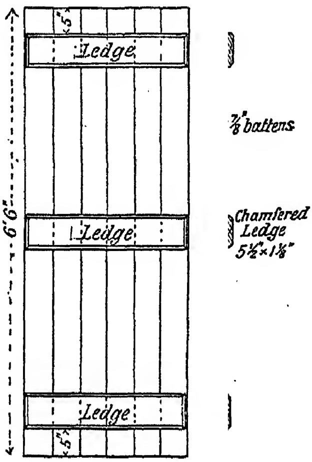
To relieve the monotony of the surface, the edges of the battens may be either beaded or V-jointed (Figs. 450 and 451). The outer edges of the cross ledges are usually chamfered, as shown in Fig. 448.

Ledged and Braced Doors.—The ledged door above described has a tendency to droop at the outer edge. To prevent this drooping, and also to strengthen the door, it is customary to insert sloping braces between the ledges. The individual braces should all slope upwards from the hinged edge. A door of this description is called a *ledged and braced door* (Fig. 449).

Framed Doors.—These are formed by constructing frames of wood, and fitting between them thinner vertical battens (in framed and ledged doors), or thin boards called *panels* (in framed and panelled doors). The object of using such a frame, either for doors or for any similar panelled work, is to obtain a structure in which the tendency to shrinkage, inseparable

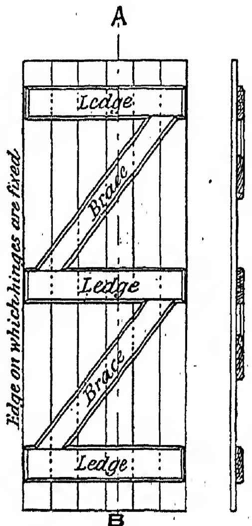
from the use of wide pieces of timber, is to a large extent obviated.

Terms used in describing Framed Doors.—The outer vertical members are called **styles**. During the construction of the door these styles are left about three inches (3″) longer than the finished door is intended to be. The projecting one and a half inches ($1\frac{1}{2}''$) at each end of the style is called a *horn*.



Back Elevation and Section of a ledged Door.

FIG. 448.



Back Elevation and Section of a ledged and braced Door.

FIG. 449.

This projecting piece of wood is left on the style to protect its corners until the door is finally fixed in position, at which time the horn is sawn off. The horizontal cross-pieces of a framed door are known as **rails**. They have distinctive names according to their position in the door, *e.g. top rail*, *frieze rail* (only used in panelled doors), *lock rail*, and *bottom rail*. The inclined members of a door—which are only used in ledged, and framed and ledged doors—are called **braces**. The vertical members separating the panels of panelled doors are known as **muntins**.

Joints used in Door Framing.—1. The **mortise-and-tenon** joint is used for connecting the frames together. The

styles have the mortises (holes) cut into them, while the tenons are left on the ends of the rails. The thickness of the tenon is from one-fourth ($\frac{1}{4}$) to one-third ($\frac{1}{3}$) the thickness of the styles and rails. When a tenon has been made very wide in proportion to its thickness, it is very liable to buckle when being wedged, and consequently to become loose if any slight shrinkage should take place. A tenon should therefore have a width of *not more than five times its thickness.* The mortise should, moreover, be a little wider at its outer edge, and thus

FIG. 450.

Tongued, grooved & beaded battens

FIG. 451.

Ploughed, tongued & V-jointed battens.

FIG. 452.

Rebated & V-jointed battens.

allow for the insertion of the wedges by which the framing is secured.

2. **Haunched Tenon.**—When part of a tenon is cut off so as to make its width less than the width of the rail, it is known as a haunched tenon. Such haunching is necessary in the top and bottom rails to enable them to be securely wedged to the style. Haunching is also necessary in the lock rails (Fig. 457) and bottom rails, so that the proper proportion of the width of the tenon to its thickness may be obtained, as well as to enable it to be firmly wedged.

3. **Bare-faced Tenon.**—This form of joint has one side of the tenon flush with one face of the rail (Fig. 457). Bare-faced tenons are used in the lower rails of a framed and ledged door (Figs. 453 to 456).

4. **Stump or Stub Tenon.**—This term is used for short tenons, such as those which occur, for example, on the end of a muntin. Stump tenons are usually about two inches (2″) long.

One of the tenons shown in Fig. 458 is known as a **double tenon.** In door construction it is only used on lock rails,

and then only where the lock is fixed into the thickness of the door. A lock so let into the style is called a *mortise lock.*

Framed, Ledged, and Braced Door.—Figs. 453 to 456 show front and back elevations, together with horizontal and vertical sections, of this kind of door. The names and dimensions of the various parts are marked in the illustrations. The styles

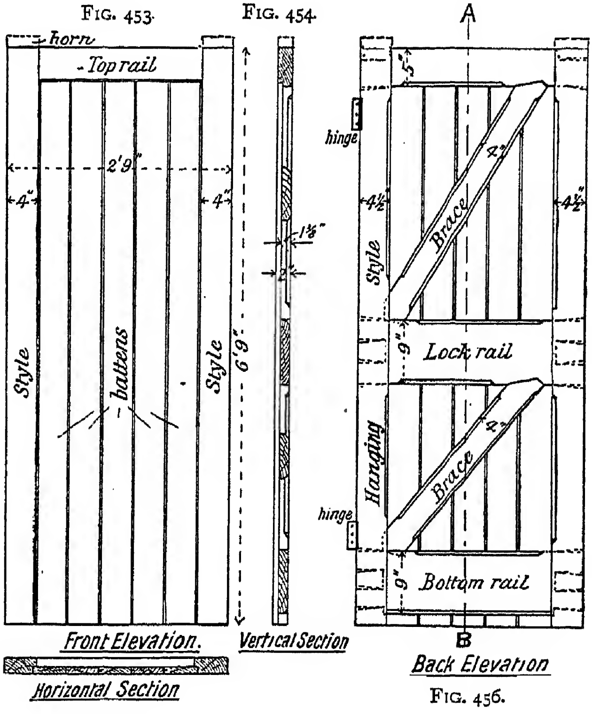


Fig. 453. Fig. 454. Fig. 455. Fig. 456.

Framed, Ledged, and Braced Door.

and top rail are of the same thickness; the lock rail, bottom rail, and braces are of less thickness than the styles, being thinner to the extent of the thickness of the battens. All the framework is flush on the inner side. In Fig. 456 the framework is shown stop-chamfered on the inner face. Such chamfering gives the door a lighter appearance. The rails and braces may be beaded or moulded as an alternative to stop-chamfering. The joints of the framing of the door under consideration are

formed as shown in Fig. 457; the lock rail and bottom rail are there seen to have bare-faced tenons. The edges of the

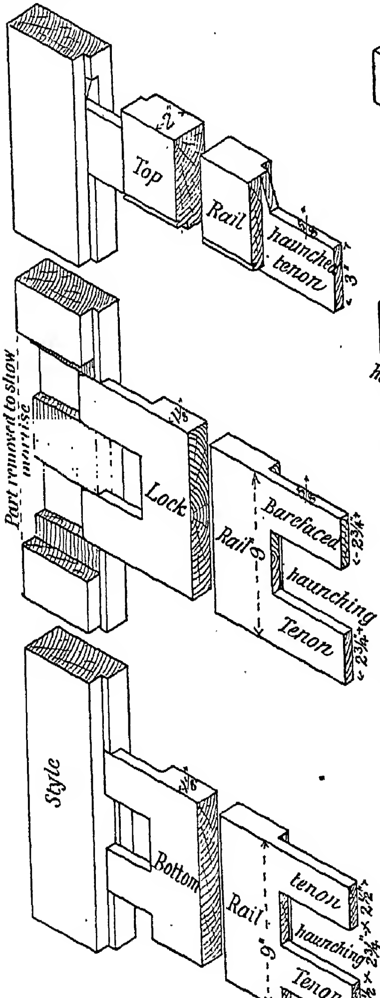


FIG. 457.—Details of Joints in Framed and Ledged Doors.

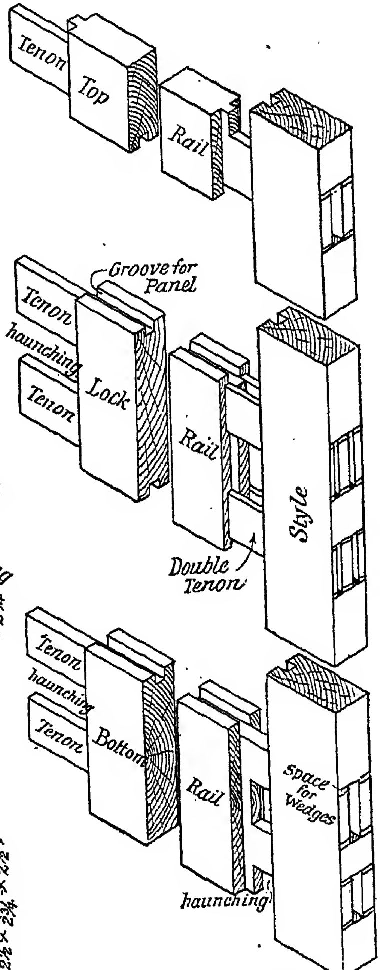
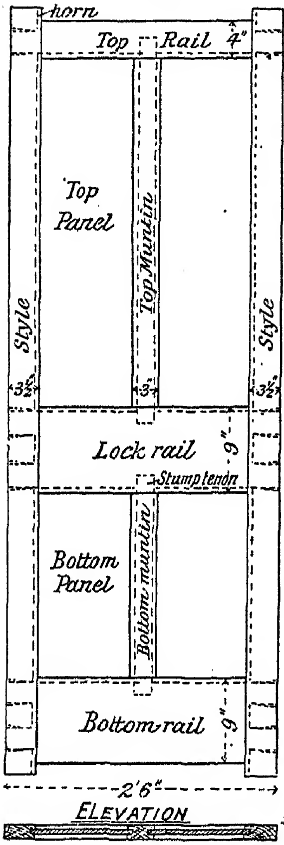


FIG. 458.—Details of Joints in Panelled Doors.

styles are rebated or grooved to receive the edges of the battens. The edges of the battens may be—

(i.) Tongued, grooved, and beaded (Fig. 450);
(ii.) Ploughed, tongued, and V-jointed (Fig. 451); or they may be
(iii.) Rebated, as shown in Fig. 452.

FIG. 459.



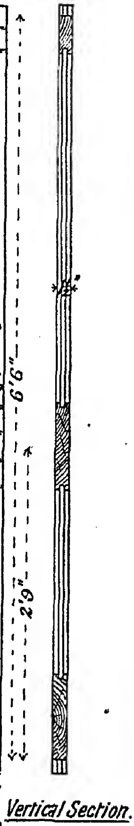
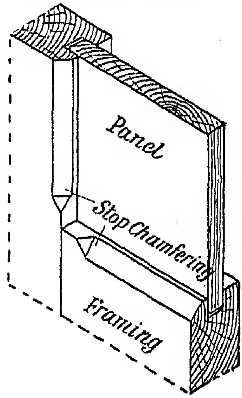


FIG. 462.—Panel ... chamfered Framing.



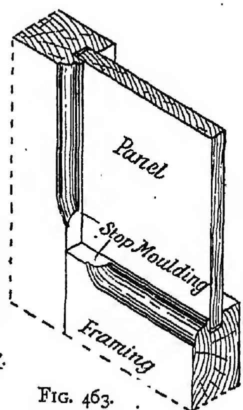


FIG. 461. FIG. 463. Panel with Stop-moulded Framing.

FIG. 460.
Elevation and Sections of a Four-panelled Door.

In arranging the braces for such a door the lower ends may be stump tenoned into the style, but the upper ends should be cut into the rail, as shown in Fig. 456. If the upper end of the brace fits into the corner as the lower end does, it is liable to

push off the joint between the rail and the style. Again, the braces must always be arranged to support the outer edge of the door, the lower end being against the hanging style.

Fig. 464.—Panelled Framing "Single Moulded."

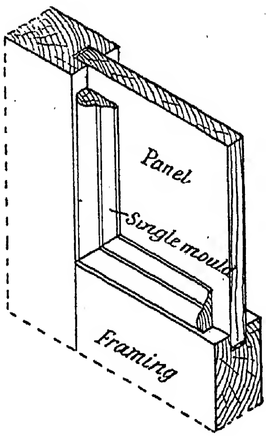
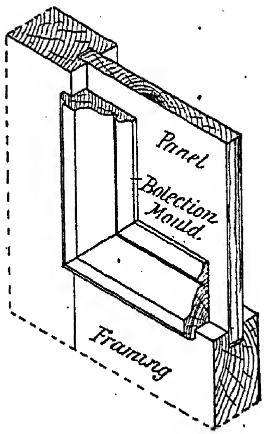


Fig. 465.—Panelled Framing "Bolection Moulded."



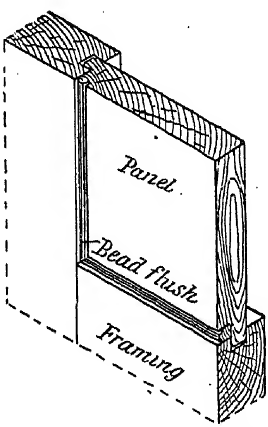


Fig. 466.—Framing with Bead-flush Panel.

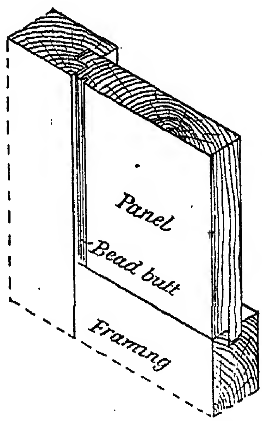


Fig. 467.—Framing with Bead-butt Panel.

Panelled Doors.—The framing for panelled doors differs from that of framed and ledged doors in that the panels—which are usually about one-third ($\frac{1}{3}$) the thickness of the door—fit into

grooves in the middle of the framing. In framed and ledged doors the framing is wedged up and finished before the battens are nailed on; while in panelled doors the panels are inserted in the grooves as the framing is put together. The grooves also affect the width of the mortises; an allowance must therefore be made for the reduced width of the tenons resulting from the grooving. This is made clear by a reference to Figs. 457 and 458.

Proportions of Panelled Doors.—Since doors vary considerably in size, arrangement, and the number of their panels, and in the methods of treatment, no hard and fast rule can be laid down as to the proportions suitable. The dimensions indicated on Figs. 459 to 461 may, however, be taken as typical. It is important to notice that the *height of the centre of the lock rail* is 2′ 9″ from the floor. This height is considered the most suitable for a lock or door fastener.

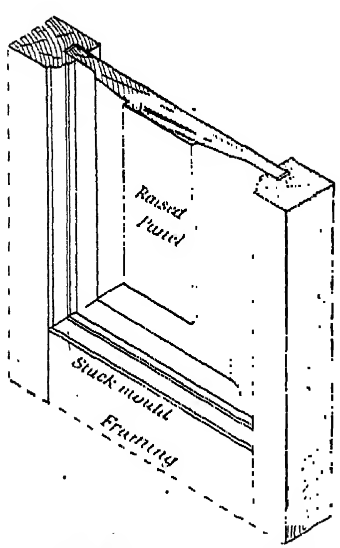


FIG. 468.—Solid-moulded Framing with Raised Panel.

Treatment of Framing.—When the framing of a door is left square, and its panels are plain and one-third ($\frac{1}{3}$) the thickness of the material of the framing, the method of finishing is named *square and flat* (Fig. 459). Square and flat treatment is, however, improved upon by *stop-chamfering* (Fig. 462), *stuck stop-moulding* (Fig. 463), *single moulding* (Fig. 464), or *bolection moulding* (Fig. 465). In the two last named an almost endless variety of sections is in use. The treatment of the framework round the panels on the same side of the same door is, of course, similar. When the panel is thicker in the middle than at the edges, so that the middle part is above the general surface, it is known as a *raised* or *fielded* panel. Fig. 468 shows an example of a raised panel. In outer doors the thickness of the lower panels is frequently made equal to two-

Fig. 469.

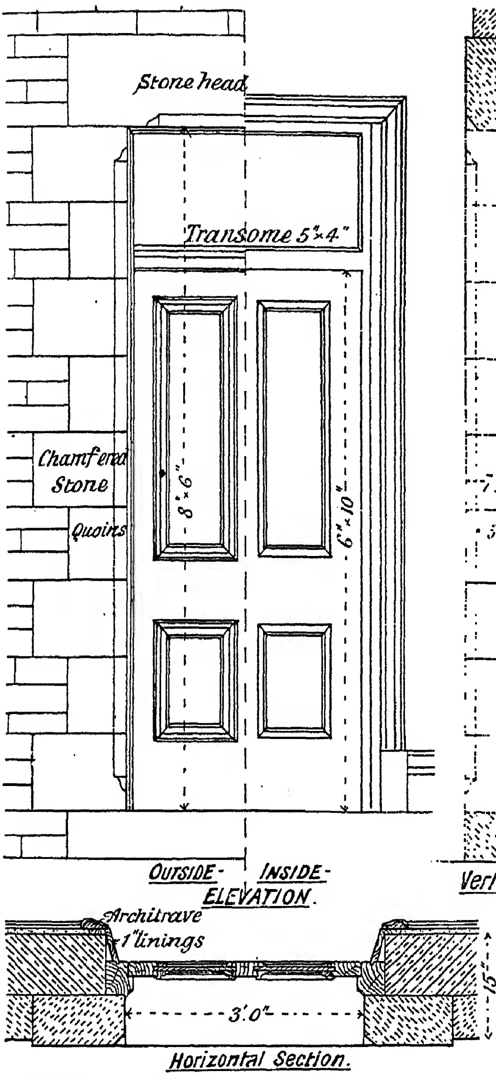


Fig. 470.

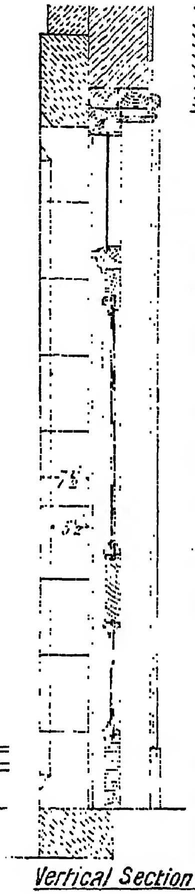
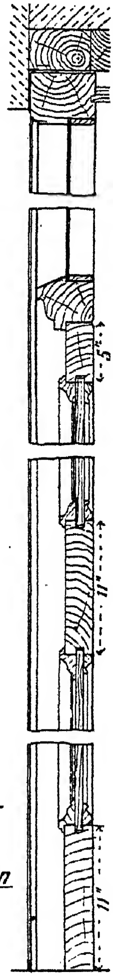


Fig. 471.
Enlarged Vertical Section.



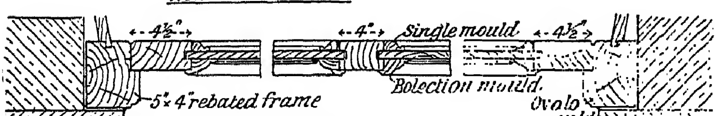


Fig. 472.—Enlarged Horizontal Section.

Details of a Four-panelled Outer Door in a Stone Wall.

thirds ($\frac{2}{3}$) the thickness of the door. In such a case one surface of the panel is flush with the surface of the framing. Figs. 466 and 467 show two methods of treating such a panel. In Fig. 466 the bead runs round the panel. This treatment is known as *bead flush*. If the vertical edges only of the panel are beaded, it is named *bead butt* (Fig. 467).

Folding Doors.—When doorways exceed three feet six inches (3′ 6″) in width, and the doors are hung with hinges, it is often advisable to have them "hung folding," that is, to have the door in two parts—each a little more than half the width of the opening—the joint where they meet being rebated. The meeting styles are usually made a little narrower than the hanging styles. Figs. 480 to 483 show the details of such a pair of folding doors.

Double-margin Doors.—A double-margin door is one

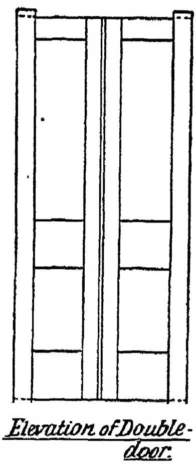


FIG. 473.

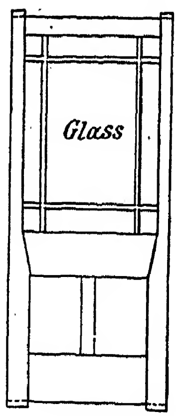


FIG. 474.

which imitates a pair of folding doors, but opens as a single door. It is made either as a single door having a very wide muntin, or as two narrow doors fastened together by means of wedges, and strengthened with wrought-iron bars, which are fixed into the top and bottom rails. In either case it has a bead running down the centre of the door. Such a bead is named a *double-quirked*, *flush*, or *centre bead* (Fig. 572). The

Fig. 475.

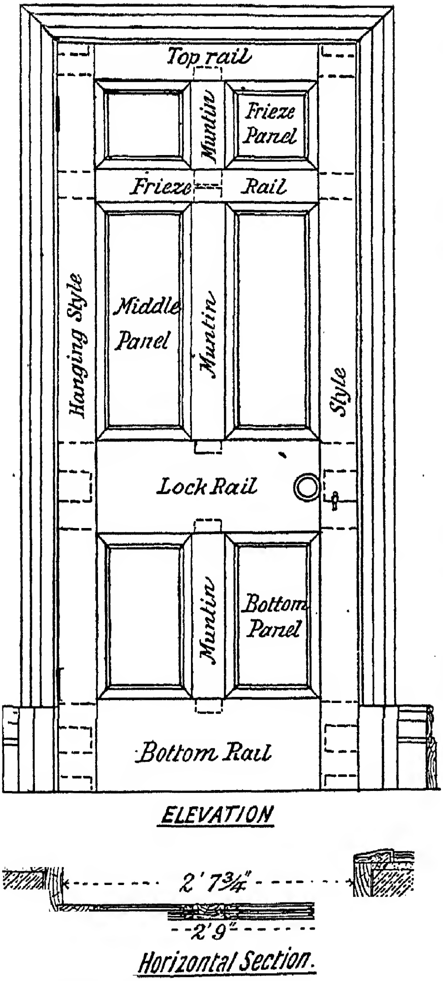


Fig. 476.

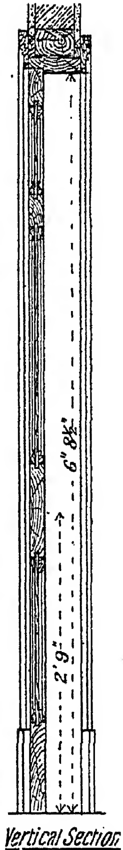
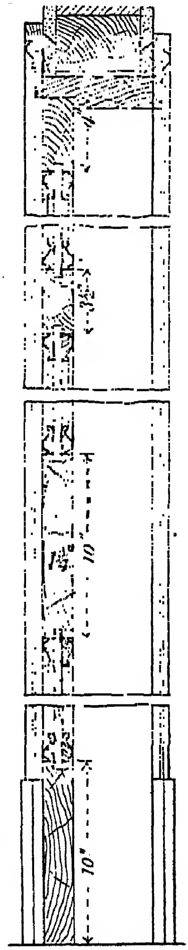


Fig. 477.
Enlarged Vertical Section.



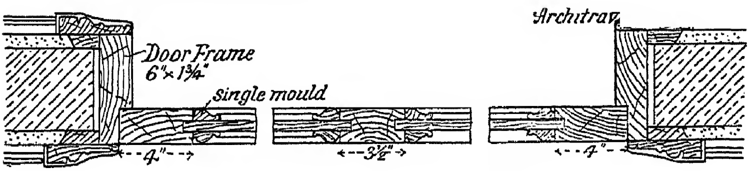


Fig. 478.—Enlarged Horizontal Section.

Details of a Six-panelled Inside Door in a 4½" Brick Wall.

double-margin door is often used for securing an improved appearance in wide, low doorways.

Sash Doors.—Sash doors are those which have the upper part prepared for glass panels. The upper portions of the styles are generally narrower than the lower parts. Such styles are named *diminishing* or *gun-stock styles.* In the upper part of the door the preparation of the framework for

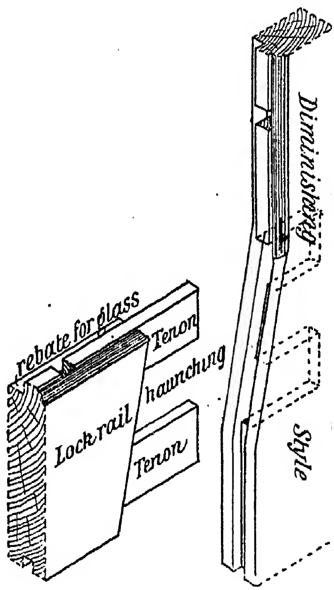


FIG. 479.—Joint between Lock Rail and Style of a Sash Door.

the glass differs from that of the grooves for wooden panels. The difference is necessary in order to allow the glass to be replaced. Fig. 474 is an elevation of a sash door. Fig. 479 is a sketch showing the joint between the lock rail and the style of such a door.

Door Frames.—There are many ways of fixing doors. An outer door has generally a solid wooden frame which fits into the recess formed in the doorway. This frame consists of two uprights named *jambs*, and a cross-piece or *head* into which the jambs are tenoned. As the door almost invariably opens inwards, the frame is rebated on the inner side to

Fig. 480.

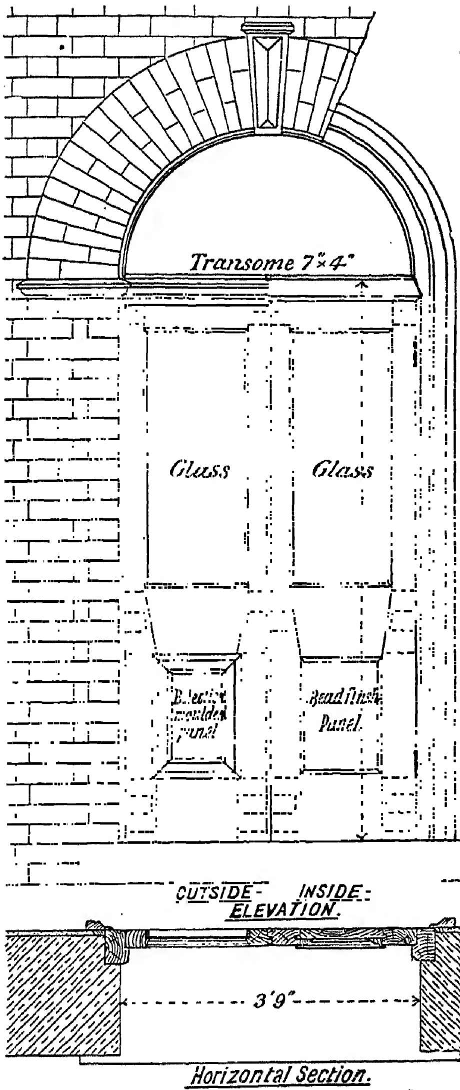


Fig. 481.

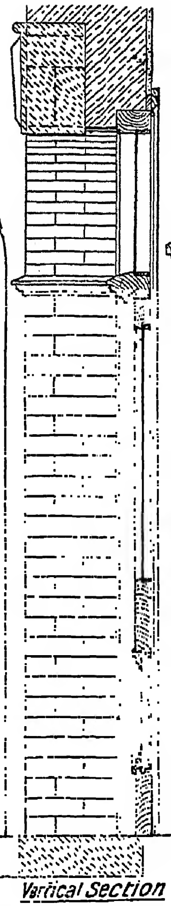
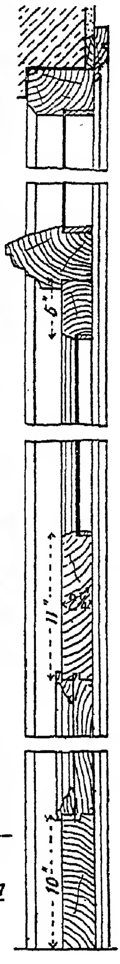


Fig. 482.
Enlarged Vertical
Section.



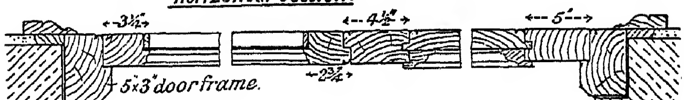


Fig. 483.—Enlarged Horizontal Section.

Details of a pair of Folding Doors (with upper Panels of Glass) in an 18″ Brick Wall.

receive the door (Fig. 484). The door frame may be either built in as the brick-work proceeds, or it may be afterwards fixed by nailing it to wooden bricks or slips built into the wall, or the nailing may be to wooden plugs driven into the joints. If the doorway is of stone, as in Fig. 485, the frames are secured by means of iron holdfasts named *split bills*, or by rag-bolts (p. 121) secured to the stone with lead. The lower

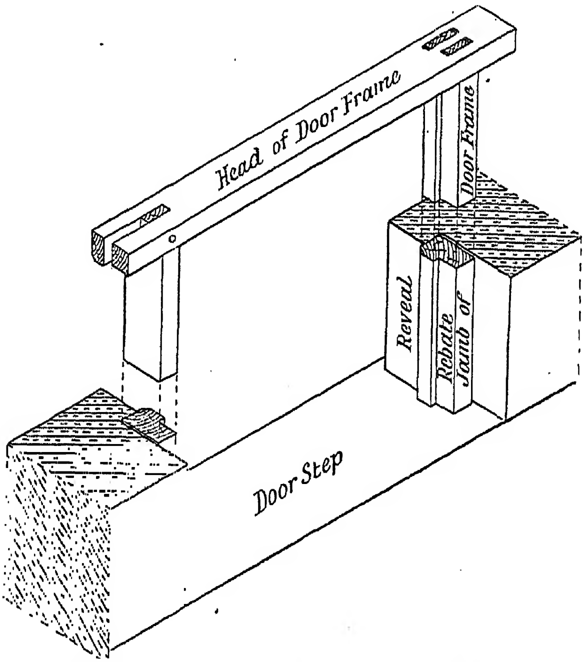


FIG. 484.—Door Frame fixed in Revealed Opening.

end of a door frame may be additionally secured by an iron dowel which fits into a hole in the door-step.

The doorway is often higher than the door, and a cross rail called a *transom* is placed across the doorway at the height of the top of the door. Above this transom is a window named a *fanlight*. The fanlight may be simply a sheet of glass secured into the rebate of the door frame, or it may have a separate frame hinged to the door frame in such a manner

that it may be opened for ventilation. The outer arris of the door frame may be chamfered (Fig. 483), beaded (Fig. 485), or moulded (Fig. 472).

Linings.—The door frame is seldom of sufficient thickness of itself to come flush with the inside face of the wall, but

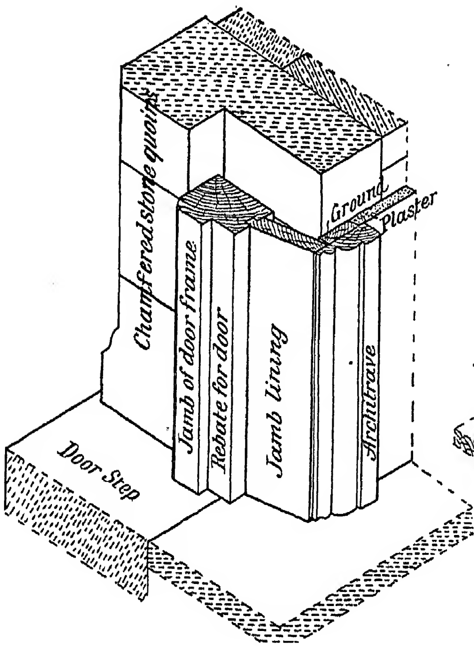


Fig. 485.—Sketch of lower part of Outer Door Frame, etc., fixed in a Stone Wall.

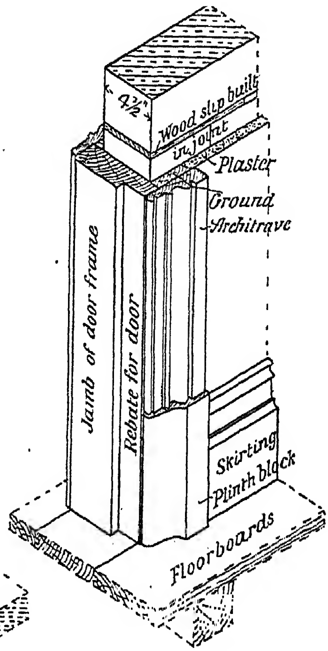


Fig. 486.
Sketch of lower part of Door Frame fixed in a 4½″ Inside Wall.

usually requires to be supplemented by *linings*, *i.e.* by boards about an inch (1″) thick, and wide enough to project beyond the inside surface of the wall for a distance of three-quarters of an inch (¾″)—the usual thickness of the plaster. The linings are tongued on one edge to fit into a groove in the door frame, and are generally *splayed*, that is, fitted at an oblique angle as shown in Fig. 485. The joint between the lining and the

plaster is covered with a mould called an **architrave**, which is fixed around the inside of door and window openings to give a finished appearance to the whole. When the wall is very thick, forming a deep recess, the linings, instead of being plain wide boards, are framed and panelled.

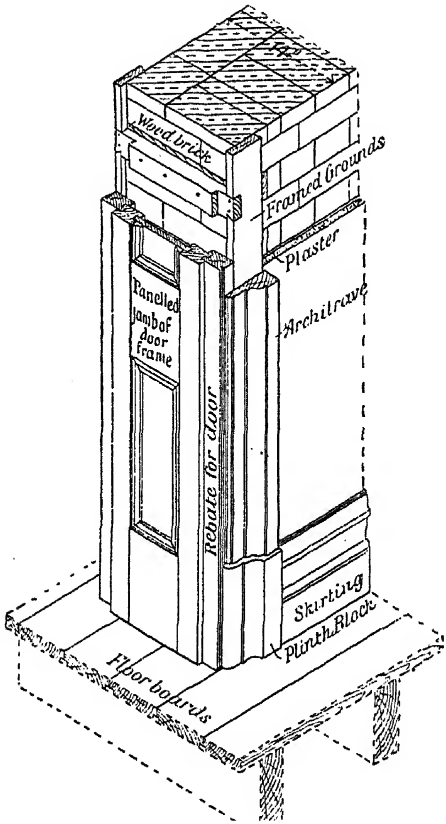


Fig. 487.—Sketch of lower part of Panelled Door Frame fixed in a 14″ Inside Wall.

Inside Door Frames.—Inside doors require frames the width of which is equal to that of the walls *plus* the thickness of the plaster on both sides. Fig. 486 is a sketch of a door frame for a four-and-a-half-inch ($4\frac{1}{2}''$) wall. In superior buildings having thick walls the inside door frames are panelled and

moulded to match the doors, and are generally rebated on both edges (Fig. 487).

Grounds.—The architraves surrounding an opening are nailed to the linings, or, when possible, to the frame. In superior work, and to form an additional support when the architraves are wide, they are also nailed to rough wooden battens or *grounds*, which have been previously fixed to the

FIG. 488.

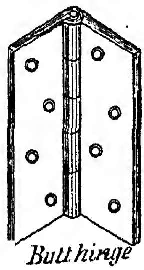


FIG. 489.

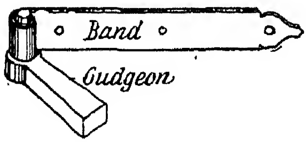


FIG. 490.

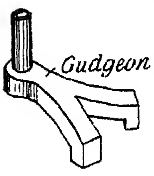


FIG. 491.

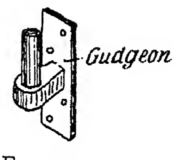


FIG. 492.

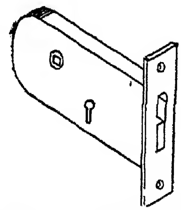


FIG. 493.—Mortise Lock.

wall in the position shown in Figs. 485 and 487. These *grounds* also serve as a guide for the plasterer. Plinth blocks are often fixed for the architraves to rest upon, as in Figs. 486 and 487. These plinth blocks serve to protect the architrave from damage, and to improve the appearance.

Hinges.—*Tee or cross-garnet hinges* (Fig. 488) are used for the commoner kinds of ledged doors. They are screwed on the surface of the door and frame.

Butt hinges (Fig. 489) are used for framed doors generally. Usually one-half of the hinge is let into the edge of the door, while the other half is let into the frame.

Spring hinges of various kinds are used when the door is required to open both ways.

Bands and Gudgeons.—Heavier kinds of framed and ledged doors, such as are used for warehouses, workshops, barracks, etc., are not fixed in any of the ways already described. Instead of having door frames, these heavy doors are often hung to heavy stones (*gudgeon* stones) built into the wall. The hanging is accomplished by means of strong *bands and gudgeons* (*hook-and-eye* hinges). These gudgeons are made secure in the stone by lead or brimstone, and the bands are bolted to the doors. Figs. 490 and 491 show different shapes of such gudgeons for stones. Fig. 492 shows a gudgeon suitable for screwing on to a wooden frame.

Heavy doors are also frequently made to slide by means of pulleys running on iron bars.

Fastenings.—The commonest kinds of doors are secured by a *thumb latch* and a *lock* or *bolt*. Fastenings which are in frequent use for securing other doors are known as *rim latches and locks*, *dead locks*, etc. *Mortise latches and locks*, so called because they are fixed into a mortise made in the edge of the door, are used in superior work.

Summary

Doors are classed as *ledged*, *ledged and braced*, *framed ledged and braced*, and *panelled*. The two latter consist of frames filled in with thinner battens and panels respectively.

The **mortise and tenon** joint is used in the construction of framed doors. The **tenon** is *bare-faced*, *haunched*, *stump*, or *double*, according to its position in the door.

The **battens** of "ledged and framed" and "ledged" doors have either *tongued and grooved*, *ploughed and tongued*, or *rebated joints*. The edges of the battens are *beaded* or V-*jointed*.

The **frame** of a door consists of *styles*, *rails*, *braces* (in ledged and braced doors), and *muntins* (in panelled doors).

Panelled framing is finished *square and flat*, *stop-chamfered*, *single moulded*, *bolection moulded*, *bead flush*, *bead butt*, or *raised* (*fielded*).

Folding doors are used for wide doorways. A *double-margin door* is one door made to imitate folding doors.

Sash doors have the upper panels of glass.

Door Frames.—Outer doors are hung to solid rebated frames fixed in reveals in the wall. *Linings* are required when the door frame is not as wide as the recess. *Inside door frames* must be wider by the thickness of the plaster than the thickness of the wall. *Architraves* surround the inner sides of outer doorways and both sides of inner doorways. *Grounds* fastened to the wall by wooden plugs are necessary for securing wide architraves.

Hinges.—*Tee* hinges, *butt* hinges, *spring* hinges, and *bands and gudgeons* are commonly used for hanging doors.

Heavy doors are often hung to large gudgeon stones by means of bands and gudgeons, or are constructed to slide with pulleys. Wooden frames are then not required.

Questions on Doors.

1. Draw, to a scale of $\frac{3}{4}''$ to the foot, the front and back elevations and a vertical section of a ledged and braced door $6' \ 9'' \times 2' \ 9''$ hung to a $4\frac{1}{2}'' \times 3''$ rebated door frame with cross-garnet hinges : $\frac{7}{8}''$ tongued, grooved, and beaded door battens; $6'' \times 1\frac{1}{4}''$ chamfered ledges; and $4'' \times 1\frac{1}{4}''$ braces.

Draw also, to a scale of $2''$ to the foot, a horizontal section of the door.

*2. Horizontal section through a door opening in a brick wall built in English bond; having a stone lintel over the outside, and a $3''$ wooden lintel, with brick relieving arch in two half-brick rings over the inside, of the opening (Fig. 494).

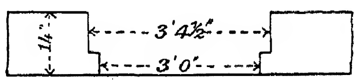


Fig. 494.

Draw, to a scale of $1''$ to the foot, front and back elevations, with vertical and horizontal sections, showing a $2''$ framed and ledged door $7' \ 0''$ high hung to a $5'' \times 3''$ rebated and chamfered solid door frame. Styles of door $5''$ wide, $\frac{7}{8}''$ battens, rebated and V-jointed.

3. An external doorway $3' \ 0'' \times 8' \ 6''$ has ashlar stone stop-chamfered quoins and stone head, with the surrounding stone-work in coursed rubble backed with $9''$ of brick-work; total thickness of wall $15''$, reveal $7\frac{1}{2}''$.

Draw, to a scale of $1''$ to the foot, one-half outside and one-half inside elevations, with vertical and horizontal sections of a $2''$ four-panelled door $7' \ 0''$ high, hung with butt hinges to a $5'' \times 4''$ rebated and moulded solid door frame; other details as shown in Figs. 469 to 472.

4. Draw, to a scale of $2''$ to the foot, enlarged vertical and horizontal sections of the door in Question 3.

5. Draw the elevation and vertical and horizontal sections of an

internal six-panelled door $6' \, 9'' \times 2' \, 9'' \times 1\frac{3}{4}''$ hung to a $6'' \times 1\frac{3}{4}''$ rebated door frame in a $4\frac{1}{2}''$ brick wall, the frame being surrounded on both sides with $4''$ architraves. The door is to be moulded on both sides, the proportions and other details being as shown in Figs. 475 to 478. Scale, $1\frac{1}{2}''$ to the foot.

6. Draw, to a scale of $1''$ to the foot, part outside and part inside elevations, with vertical and horizontal sections, of the doorway and folding doors shown in Figs. 480 to 483. The height of the door is $7' \, 3''$; other dimensions as shown on the figure.

Examination Questions

7. Draw, to a scale of $\frac{1}{2}''$ to a foot, the back elevations of both a ledged door and a framed and braced door; to be $7' \times 3'$, and put together in batten widths.

*8. Elevation of the back of a framed and braced door (Fig. 495).

Draw, to a scale of $\frac{3}{4}''$ to a foot, making any alteration you think advisable, and filling in with rebated and beaded battens. Only the joints in connection with the hanging style to be dotted in.

*9. Front elevation of a framed and braced door with $6''$ styles,

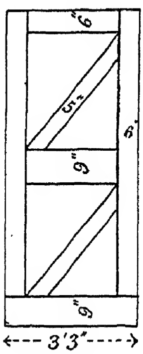


Fig. 495.

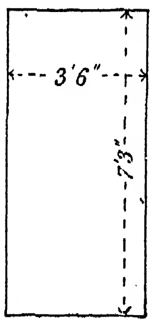


Fig. 496.

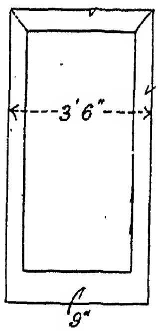


Fig. 497.

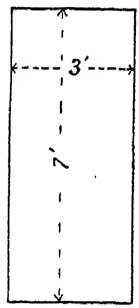


Fig. 498.

$7''$ top rail, $9''$ bottom rail, $10''$ lock rail, and $6''$ braces, and filled in with $5''$ battens (Fig. 496).

Draw, to a scale of $\frac{1}{18}$, showing by dotted lines the members at the back of the door.

* 10. Outside elevation of a framed and braced outer door (Fig. 497).

Draw, to a scale of $\frac{3}{4}''$ to a foot, making any alterations you consider necessary, and filling in with chamfered battens.

The joints to be shown by dotted lines, as well as the rails and braces not seen.

* 11. Elevation of the back of a ledged and braced battened door (Fig. 498).

Draw, to a scale of $\frac{3}{4}''$ to a foot, showing it hung to a $2''$ frame, with cross-garnet strap hinges.

12. Draw, to a scale of $\frac{3}{4}''$ to a foot, both the front and back elevations of a $1\frac{1}{4}''$ ledged and braced battened door $3' \times 6'\ 6''$.

Give a full-sized section through a joint between two of the battens, showing it ploughed and tongued, chamfered one face, and beaded on the other.

13. Draw a horizontal section through the jamb of an external doorway in a store, showing a $14''$ brick wall, with bull-nose dressings outside, $5'' \times 4''$ solid frame, rebated and beaded, and the hanging style of a $2\frac{1}{4}''$ framed and braced door, including two rebated and beaded battens of same.

* 14. Elevation of the head of a solid door frame (Fig. 499).

Draw, to a scale of $\frac{3}{4}''$ to a foot, making any alteration you think necessary.

Give a section through *A*—*A*, showing a beaded frame, rebated for a $2\frac{1}{4}''$ door.

* 15. Horizontal section through a four-panelled door $7'$ high (Fig. 500).

Draw its outside elevation, and a vertical section through *a*—*a*, to a scale of $\frac{3}{4}''$ to a foot, showing the top panels bead butt and the bottom panels bead flush.

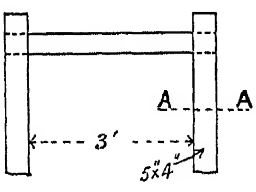


FIG. 499.

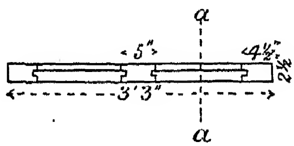


FIG. 500.

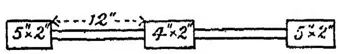


FIG. 501.

* 16. Horizontal section through a door (Fig. 501).

Draw, to a scale of $1\frac{1}{2}''$ to a foot, showing one panel bead flush one side and square and flat at back; and the other filled in solid.

17. Draw a horizontal section through a $2\frac{1}{2}''$ framed and panelled door to a scale of $\frac{1}{4}$.

The door to be $3'.6''$ wide, with $5''$ margins, one panel to be square and flat and moulded one side, and the other to be bead butt both sides.

*18. Elevation of a six-panelled door, framed square and flat (Fig. 502).

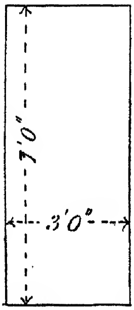


FIG. 502.

Draw, to a scale of $\frac{3}{4}''$ to a foot, showing all the details of construction, and writing their names on the different parts.

19. Draw an elevation of a six-panelled door $7' \times 3'$, writing their names on the different parts, and showing the difference between panels square and flat, bead butt, and bead flush, stating which is which. Also show by dotted lines how the parts are framed together.

20. Draw a horizontal section, to a scale of $\frac{1}{6}$, through one jamb of a 3' doorway in a 14" brick wall, showing a $4\frac{1}{2}''$ reveal and the bricks laid in Flemish bond, a solid frame $5'' \times 4\frac{1}{2}''$, rebated and chamfered, and about half the door, which is to be framed and braced, $5'' \times 2''$ hanging style, and $4\frac{1}{2}'' \times \frac{3}{4}''$ battens.

21. Give, to a scale of $\frac{1}{6}$, a horizontal section through one jamb of an entrance doorway to a dwelling-house, the outer walls being 18" brick-work with chamfered stone quoins to openings.

The following to be shown :—

Inner face of wall plastered flush with door frame.

Single architrave to door frame.

Hanging style of door $6'' \times 2\frac{1}{2}''$.

Panel (part only) bead flush and moulded at back.

22. Draw a horizontal section through a little more than half of an external doorway in a 20" stone wall, with ashlar quoins and rendered on the inner face.

The section to be to a scale of 1" to a foot, through one panel of a 2" six-panelled door, hung folding, bead flush outside and square and flat at back, to proper solid frame, with plain linings and chamfered architraves.

Internal width of frame to be 3' 9".

CHAPTER XII

WINDOWS

Size and Position.—The sizes and positions of window openings are influenced by the size of the rooms, and the purposes for which the building is used. For the sake of ventilation, and also to secure good lighting, they should be placed at as great a height as the construction of the room will allow. In dwelling-houses the height of the sill is usually about two feet six inches (2′ 6″) above the inside floor-level.

Construction.—The framework holding the glass of the window may be fixed or movable. It must be so prepared that the glass can be easily replaced when necessary. In warehouses, workshops, and similar buildings, the frames holding the glass are often fixed as *fast sheets* (Fig. 503). As, however, this arrangement affords no means of ventilation, it is more usual to have the glass fixed in lighter frames called **sashes.** If the sashes are hung to solid rebated frames and open like doors, the windows are called **casement windows.** If they slide vertically and are balanced by weights, the window is a **sash and frame window.** Other methods of arranging sashes are illustrated in Figs. 532, 533, and 534.

Sashes.—The terms used for the various parts of sashes and fast sheets are somewhat similar to those employed in describing doors. Thus, the *styles* are the outer uprights, and the *rails* are the main horizontal cross-pieces; top rails, meeting rails, and bottom rails being distinguished. Any intermediate members, whether vertical or horizontal, are named *bars*.

Sashes are from one and a half to two and a half inches

($1\frac{1}{2}''$ to $2\frac{1}{2}''$) thick. The inner edge of the outer face is rebated to receive the glass. The inner face is left either square,

FIG. 503.

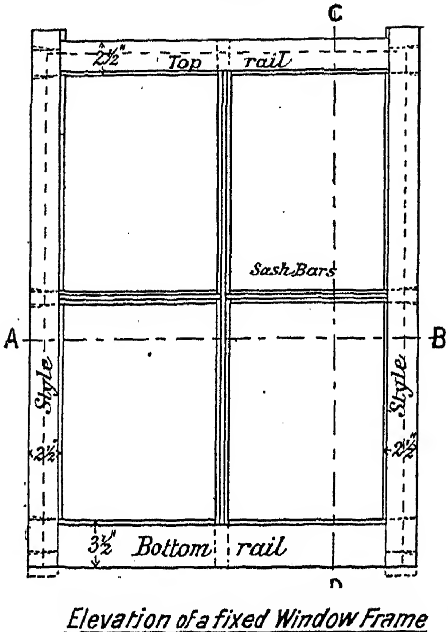


FIG. 504.

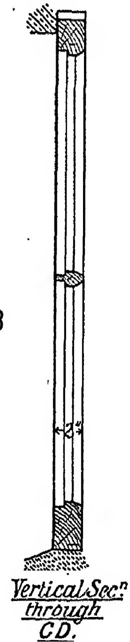


FIG. 505.

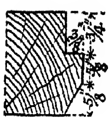


FIG. 506.

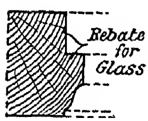


FIG. 507.

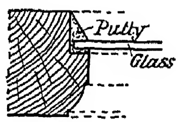


FIG. 508.

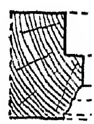


FIG. 509.

Alternative Sections of Sash Framing.

chamfered (Fig. 506), or moulded. Two common forms of moulding are *lamb's-tongue* (Fig. 507) and *ovolo* (Fig. 508). The size of the rebate is indicated in Fig. 506. It varies with the thickness of the sash, its depth being always a little more

than one-third ($\frac{1}{3}$) this thickness. The mould is usually sunk the same distance as the rebate.

In general, the style and top rail are, before being rebated, square in section. In casement sashes, however, the outer styles often require to be a little wider than the thickness, as will be explained later. The width of the bottom rail is from one and a half to twice the thickness of the sash. Sash bars, which require rebating and moulding on both sides, should be as light as possible in order not to interrupt the light. They are usually from five-eighths to one and an eighth inches ($\frac{5}{8}''$ to $1\frac{1}{8}''$) wide.

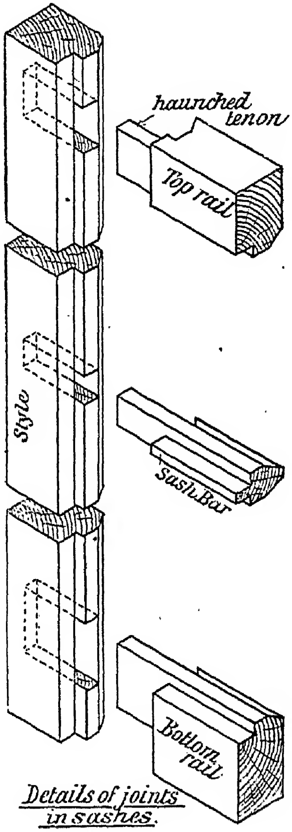


FIG. 510.

Joints of Sashes.—The sashes are framed together by means of the *mortise and tenon* joint (p. 170). The remarks made (p. 171) in the chapter on doors, concerning the thickness of the tenon and haunched tenons, are to a large extent applicable here also. The best joint for connecting sash bars is shown in Fig. 511. This method is known as *halving*. An alternative to halving in sash bars is to arrange the bar which is subjected to the greater stress (as, for example, the vertical bars in sliding sashes, and the horizontal bars in hinged casement sashes) to be continuous; this continuous bar is mortised to receive the other, on which short tenons are left, and which is *scribed*, *i.e.* cut, to fit the first. This method is called *franking* the sash bars, and is illustrated in Fig. 512.

Casement Windows.—Casement windows may be hinged in such a manner that they open either inwards or outwards. They may consist either of one sash, or of two

folding sashes, and are hung with butt hinges (p. 185) to solid rebated frames. These frames consist of jambs, head, and sill. The head and sill "run through" and are mortised near

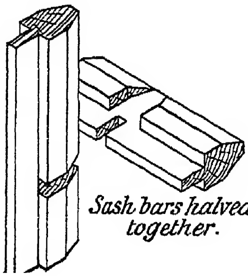


FIG. 511.

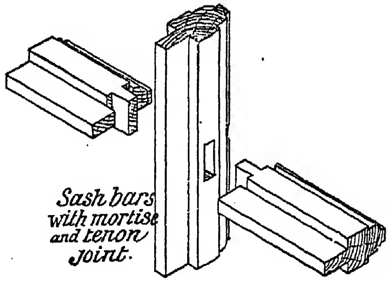


FIG. 512.

the ends to receive tenons formed on the ends of the jambs. The upper surface of the sill is weathered (p. 38) to throw off the water.

Casement Sashes opening Inwards.—Figs. 513 to 516 show the elevation, and vertical and horizontal sections, of a window-opening in a fourteen-inch (14″) brick wall, surmounted by a straight-gauged brick arch, having a stone sill, and fitted with a casement window having folding sashes to open inwards. In this class of window the frame is rebated on the inner side. Each sash has a semicircular tongue on the outer style, which fits a corresponding groove in the jamb of the frame. This tongue renders the window more likely to be weatherproof, though it is often omitted, as in Fig. 517. The extra width of style already referred to is here necessary. The greatest difficulty is, however, found in making a watertight joint between the bottom rail of the sash and the sill of the frame. Figs. 517 and 518 show two methods by which this may be accomplished. An essential feature of all these sashes is a small groove or throating on the under edge of the bottom rail. This prevents the water from getting through. The groove in the rebate of the sill (Fig. 518) is provided to collect any water which may drive through. This water escapes through the hole bored in the centre of the sill. When casement sashes are hung after the manner of folding doors, the joint between the meeting styles is rebated.

Alternative methods of rebating are shown in Figs. 519 and 521.

FIG. 513. FIG. 514. FIG. 515.

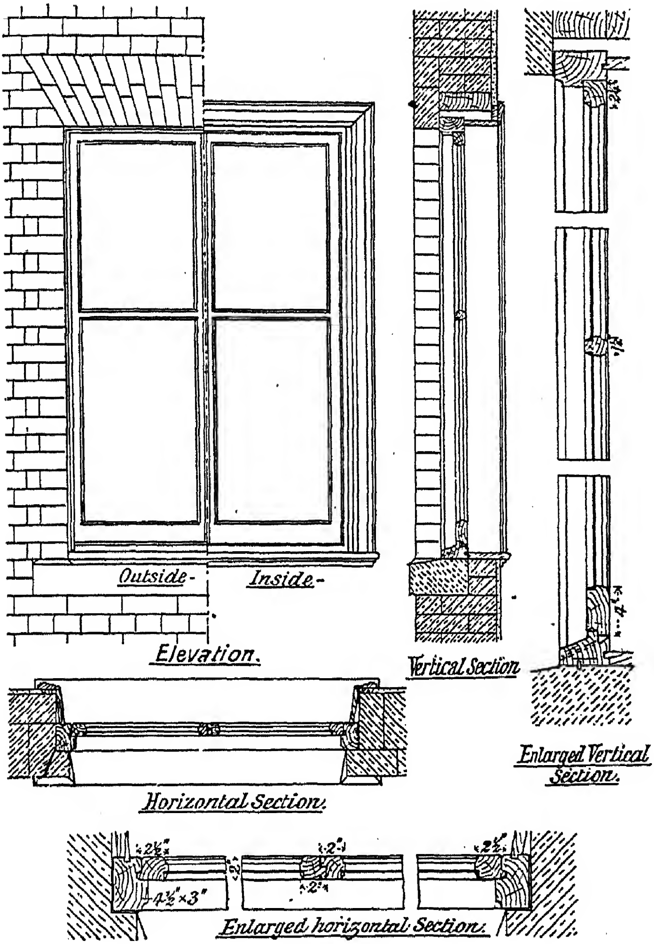


FIG. 516.

Details of a Casement Window with Sashes opening inwards, fixed in a 14″ Brick Wall.

Casement Sashes opening Outwards.—These are more easily made weatherproof than inward-opening sashes. The chief objections to their adoption are that they are not

FIG. 517.

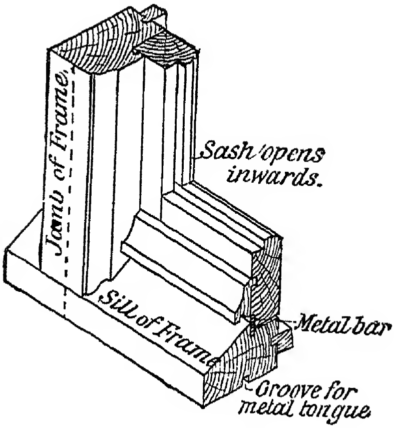
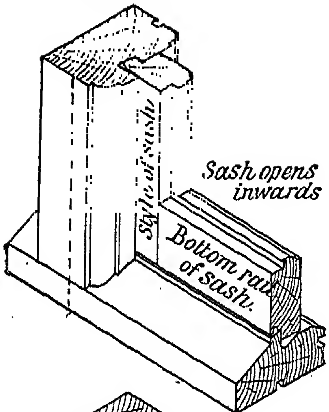


FIG. 518.



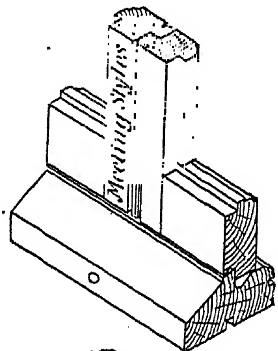


FIG. 519.

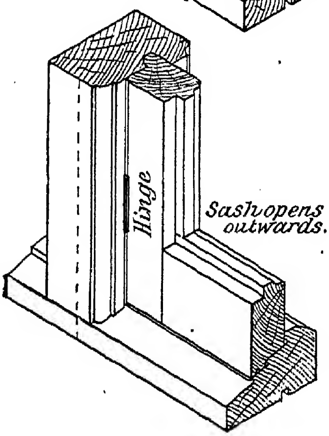


FIG. 520.

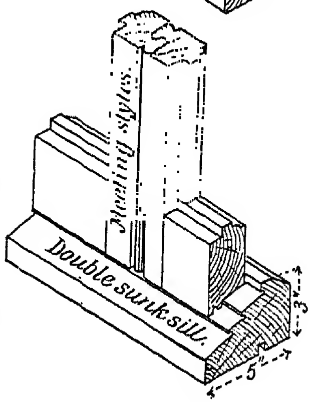


FIG. 521.

Sketches showing alternative methods of arranging Casement Sashes in the Frames.

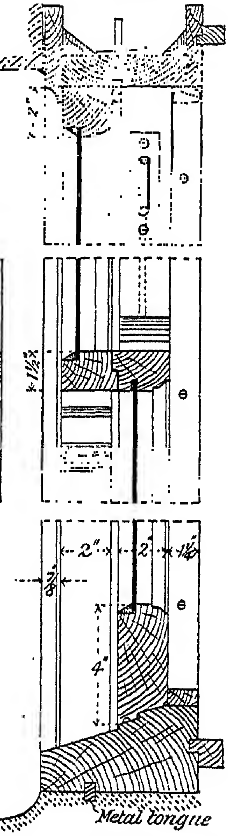
easily accessible for cleaning, especially in upper rooms, and that they are also liable, when left open, to be damaged by high winds. Fig. 520 is a detailed sketch of one corner of such a sash. It will be noticed that these frames, like door frames, have the exposed arrises moulded in various ways, and that the sashes may be either hung flush with one face of the frame as in Figs. 516 and 517, or may fit in the thickness of the frame (Figs. 518 and 520).

Sash and Frame.—In this class of window, which is by far the most common, there are two sashes, which slide past each other in vertical grooves, and are balanced by iron or leaden weights. As will be seen from Fig. 522, the frames form cases or boxes in which the weights are suspended. They are hence called **cased frames.** *Pulley styles* (Fig. 522) take the place of the rebated jambs of casement windows. The pulley styles, outside and inside linings, and back lining (Fig. 522) together form a box which is generally subdivided by a vertical *parting slip* suspended as shown in the figure. In superior window frames of this kind the pulley styles and linings are tongued and grooved together as shown in Fig. 525. In commoner work the tongues and grooves are often omitted. The frame must be so constructed that the sashes can easily be removed for the purpose of replacing broken sash-lines. The edge of the inside lining is therefore made flush with the face of the pulley style, while the edge of the outside lining projects for a distance of about three-quarters of an inch ($\frac{3}{4}''$) beyond this face to form a rebate against which the outer (upper) sash slides. The outer sash is kept in position by the *parting lath* (Fig. 522), which fits into a groove in the pulley style. The groove for the inner (lower) sash is formed by this parting lath and a *staff bead* (Fig. 522) which is secured by screws. A vertical section through the *head* of the frame is similar to a horizontal section across the pulley style, except that the back lining and parting slip are of course absent (Fig. 522). The *sill* of the frame is solid and weathered, and should always be of hard wood. It has a width equal to the full thickness of the frame. When the weathering has two steppings, as in Fig. 522, the sill is known as a *double-sunk sill.* In order to render the joint between the wooden and stone sills of window frames water-tight, a

metal tongue is often fixed into corresponding grooves cut on the under surface of the wooden sill and on the upper surface of the stone sill (Figs. 524 and 526).

FIG. 523.

FIG. 524.



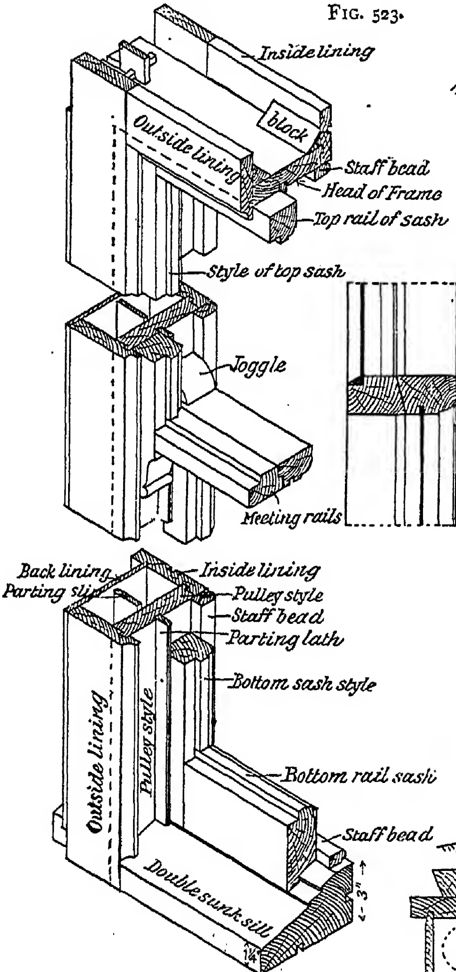
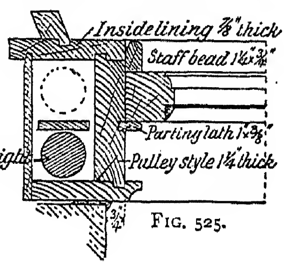


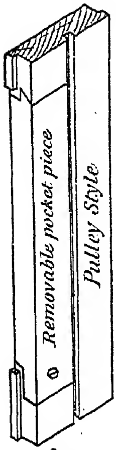
FIG. 522



Details of a Sash and Frame Window.

FIG. 525.

FIG. 52'



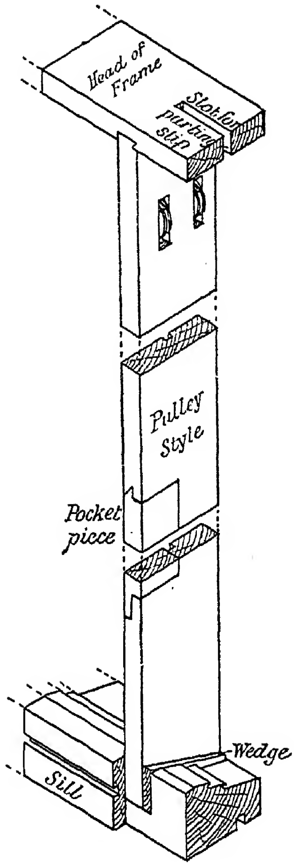


FIG. 528.—Joints at ends of Pulley Style.

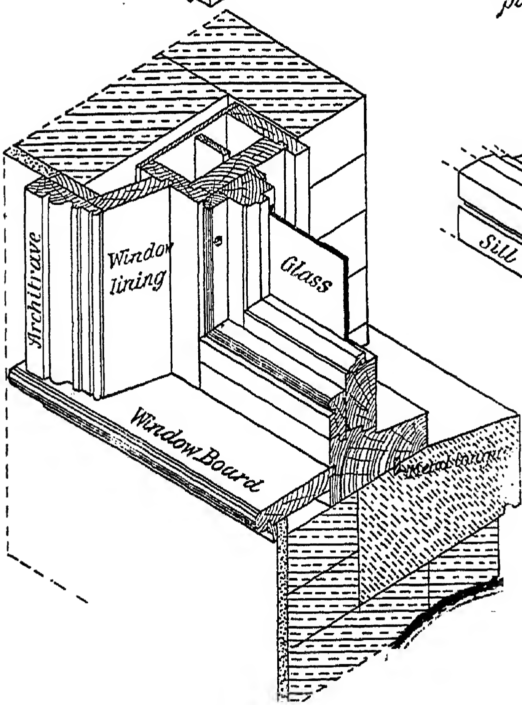


FIG. 526.—Sketch of one Corner of

Fig. 528 shows the method of fixing the pulley style into the head and sill respectively. The pulleys on which the sash lines run are fixed in mortises near the upper end of the pulley style. It is also necessary to have a removable piece in the lower part of each pulley style to allow of access to the weights. This piece is named the *pocket piece*. It is generally cut as shown in Fig. 527, its position being behind the lower sash, so that it is hidden from view when the window is closed.

The staff bead on the sill is often made about two inches (2″) deep to allow the lower sash to be raised sufficiently for ventilation at the meeting rails without causing a draught at the bottom (Fig. 526).

Sashes.—The only difference between the joints of these sashes and those of casement sashes already described is in the construction of the meeting rails. Each of these requires to be thicker than the sash by the thickness of the parting lath, otherwise there would be a space between these rails equal to the thickness of the parting lath. The joint between them may be rebated (Fig. 524) or *splayed* (Fig. 523). The joints between the meeting rails and sash styles are much stronger if the styles are made a little longer and the projecting part moulded, as shown in Fig. 522. Such projections are called *joggles*, and assist in enabling the sashes, especially in wide windows, to slide more freely. When, as is usually the case, both sashes slide, and are balanced by weights, the window is known as a *double-hung* sash and frame window. If one sash only slides, and the other is fixed in the frame, the window is *single-hung*.

Figs. 529, 530, and 531 are elevation and vertical and horizontal sections respectively of a sash and frame window fixed in an opening in a fourteen-inch (14″) brick wall having a stone head and sill.

Other Methods of Arrangement.—Methods of arranging sashes which it is necessary to be able to open for purposes of ventilation, etc., but which are in positions difficult of access, are shown in Figs. 533 and 534. Fig. 532 is the elevation of a window the lower sash of which is fixed in the frame, the upper sash being hinged on the bottom rail to open inwards. The bottom rail is rebated to fit the *transom* (the horizontal member of the window frame). The transom is weathered and double-

sunk, as shown in the enlarged section given in Fig. 533. Such an arrangement is also applicable to a fanlight over a shop

FIG. 529.

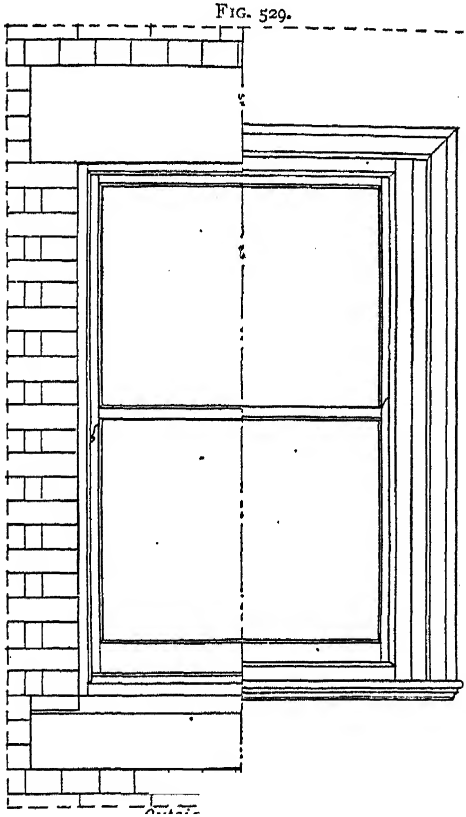
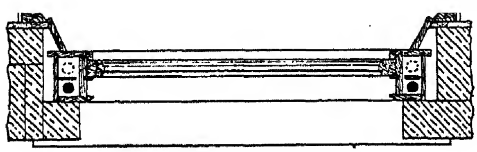


FIG. 530.

Vertical Section.



Horizontal Section.

FIG 531.

Elevation and Sections of a Sash and Frame Window, fixed in a 14″ Brick Wall.

door, where the sash may be conveniently made to fit into the rebate of the door frame.

Another method of arranging the sash is shown in section in Fig. 534. Here the sash swings on iron pins or pivots. The pivots are placed a little above the middle of the sash, so that the lower part (which always swings outwards) is heavier than the upper. This facilitates the closing of the window. The rebate on the lower part of the frame must of

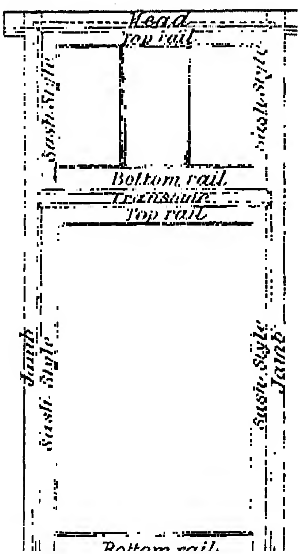
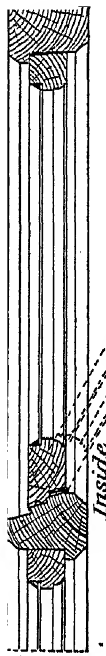
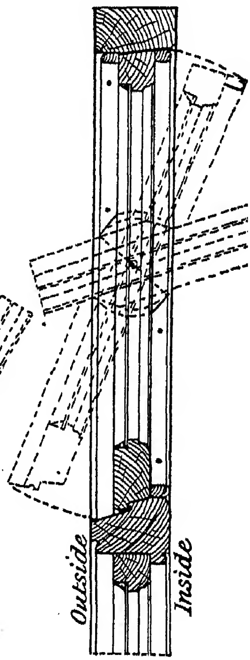


FIG. 532.—Elevation of Window with Upper Sash to open.



Upper sash hinged to open inwards.

FIG. 533.



Sash to swing on pivots or sash centres.

FIG. 534.

Enlarged Sections through Upper Sash of Fig. 532.

necessity be inside, and the rebate of the upper part must be outside. To secure uniformity of appearance, a bead is run round the sash along both styles and the top rail and on each side of the sash. It is therefore necessary to have the lower part of the outside bead and the upper part of the inside bead *fixed to the sash.* These points will be clear from a careful

inspection of Fig. 534. Occasionally the styles of the sash and the jambs of the frame are rebated "out of the solid." This, however, involves increased labour, and is seldom done.

Fixing Window Frames.—Window frames may be built into the opening as the brick-work proceeds, or they may be fixed later. In the former case, the ends of the sill and head project and form *horns*, which are built into the brick-work and help to secure the frame. Wooden bricks or slips may also be built into the wall, the frames being nailed to them.

In the latter case, the frames are secured by wooden wedges which are driven tightly in between the frame and the wall. These wedges should be inserted only at the ends of the head and sill and directly above the jambs, or the frame may be so strained as to affect the sliding of the sashes. Window frames as well as door frames should be bedded against a layer of hair-mortar placed in the recess.

Linings.—When window frames are not of sufficient thickness to come flush with the inner face of the wall, the plaster may be returned round the brick-work and finish against the frame. In dwelling-houses, however, the more usual way is to fix linings similar to those used for outer-door frames (p. 183). The linings vary in width according to the thickness of the wall, and project beyond the inner face of the wall for a distance equal to the thickness of the plaster. When the walls are very thick, the linings may be framed and panelled. The insides of window and door openings are usually finished similarly; thus, the architrave, which is secured to rough wooden grounds, is fixed along the sides and top in both cases.

The bottom of the window-opening is finished with a *window board*, which is tongued into the sill. The board is about one and a quarter inches ($1\frac{1}{4}''$) thick, and is made wide enough to project beyond the surface of the plaster for a distance of about one and a half inches ($1\frac{1}{2}''$). The projecting edge is rounded (nosed) or moulded. It is longer than the opening, to allow the lower ends of the architraves to rest upon it.

Fastenings.—There are so many window-fasteners in general use that it is unnecessary to enumerate them all. Casement sashes may be fastened when closed by means of *tower* or *flush bolts*. The sashes may be held in any required position when open by a flat bar of iron or brass, which is

pivoted and screwed to one sash or to the sill of the frame. The bar is pierced at intervals with holes, which fit a pin screwed to the other sash. Sliding sashes are secured by a sash-fastener screwed on the meeting rails. Hinged sashes (Fig. 533) are usually furnished with an iron quadrant, which is screwed to the frame and the sash, and regulated by a cord. Pivoted sashes are regulated by means of a cord passing over pulleys.

Summary

Windows may be either fixed or made to open. Those which open consist of a **frame** and movable **sashes**, which are rebated to hold the glass.

In **casement windows** the sashes open like doors. They may open inwards or outwards. The frame is solid and rebated.

In **sash and frame windows** the sashes slide vertically alongside each other, and are balanced by weights. The upper sash always slides in the outer groove. The frame consists of several parts which together form on each side a box or case in which the weights are suspended.

Sashes hinged on the bottom rail to open inwards, and sashes swinging on pivots, are sometimes used, especially in positions not easily accessible.

Sashes are framed together with *mortise and tenon* joints.

Linings and **architraves** are required with thick walls to obtain a finished internal appearance.

Questions on Windows

1. Draw, to a scale of 2″ to the foot, the elevation and vertical section of a fixed window frame for an opening 2′ 9″ high and 2′ 3″ wide; styles and top rail, $2\frac{1}{2}'' \times 2''$; bottom rail, $3\frac{1}{2}'' \times 2''$; sash bars, $\frac{7}{8}''$ thick; the frame to be rebated and chamfered.

2. Figs. 513 to 516 show details of 2″ casement sashes hung folding to a solid rebated frame, and arranged to open inwards.

Draw out the same to a scale of 1″ to the foot, with enlarged sections to a scale of $\frac{1}{4}$ full size. Size of opening $6' \, 0'' \times 4' \, 0''$; walls 14″ thick, reveals $4\frac{1}{2}''$ wide.

3. Draw, to a scale of 4″ to the foot, a section through the head and sill, and a horizontal section through one side, of a casement window with the sashes opening outwards. Dimensions of frame and sashes as in Question 2.

4. Draw elevations and sections of a sash and frame window $5' \, 6'' \times 3' \, 6''$, from details given in Figs. 522 to 531. Wall, 14″ thick. Scale, 1″ to the foot.

Draw enlarged sections, to a scale of $\frac{1}{3}$ full size.

EXAMINATION QUESTIONS

*5. Horizontal section through a window 1′ 8″ × 2′ 6″, to be fitted with a casement sash, hung to a solid frame, and opening inwards (Fig. 535).

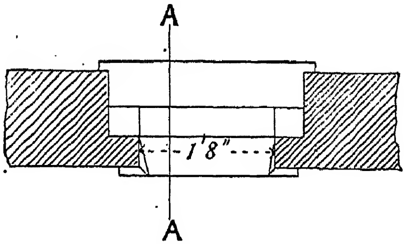


FIG. 535.

Draw a vertical section through *A—A*, to a scale of $1\frac{1}{2}''$ to a foot, showing a stone head and sill, a $1\frac{1}{4}''$ window board, and a 2″ sash, which must be weather-tight.

6. Give a horizontal section, to a scale of $\frac{1}{6}$, through a little more than half of a French casement window, 3′ 6″ wide, in an 18″ wall, showing folding sashes opening outwards.

The inside of the frame to be flush with the inside of the wall, and the joint between the frame and wall to be covered with a plain chamfered architrave. Give a freehand section of the bottom rail and sill, showing how you would keep out the weather.

7. Give, to a scale of $\frac{1}{3}$ full size, a horizontal section through one side of a window-opening in a 14″ brick wall, showing all the details connected with a wooden cased frame for 2″ double-hung sashes, with half-brick reveals and plastered jambs. The joints of the brick-work need not be shown.

The following dimensions to be adopted:—1″ inside lining, $1\frac{1}{4}''$ pulley style and outside lining, $\frac{3}{8}''$ parting bead, $\frac{1}{2}''$ back lining and parting slip, $1\frac{1}{2}'' \times \frac{3}{4}''$ inside bead. A sash style to be shown.

8. Draw, $\frac{1}{4}$ full size, a horizontal section through one side of a sash frame in a 14″ brick wall, including the style of the lower sash, which is to be 2″ ovolo moulded.

Put their names against the different parts.

9. Draw, to a scale of $\frac{1}{4}$, a horizontal section through a window jamb in a 14″ wall, showing the details of a cased frame for 2″ double-hung moulded sashes.

Give the section of the sash style, and write their names and dimensions against the different members of the frame.

10. Give vertical sections, half full size: 1st, through the

bottom sash rail and the oak sill of a $1\frac{1}{2}''$ double-hung window; 2nd, through the meeting rails.

*11. Front elevation of a gauged brick arch over a window-opening in a $14''$ brick wall (Fig. 536).

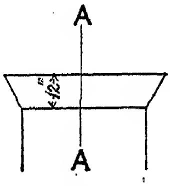


FIG. 536.

Draw, to a scale of $1\frac{1}{2}''$ to a foot, a cross section through *A—A*, showing a $3''$ lintel, with a rough discharging-arch in two half-brick rings; also a $1\frac{1}{2}''$ head to window frame, with $\frac{3}{4}''$ inside and $\frac{1}{2}''$ outside linings, $\frac{3}{4}''$ soffit lining, and the upper rail of a $1\frac{3}{4}''$ top sash.

12. Give a vertical section, to a scale of $\frac{1}{6}$, through the sill of a double-hung window sash, showing a stone sill $11'' \times 6''$, resting on a $14''$ brick wall, an oak sill $6'' \times 3''$, a $1\frac{1}{2}''$ window board, and the bottom rail of a $2''$ sash.

Also give a cross section through the meeting rails.

13. Draw a vertical cross section, to a scale of $1\frac{1}{2}''$ to a foot, *through the bottom of a window opening, showing an oak sill* $7'' \times 3''$, weathered and grooved for iron tongue; a stone sill $9'' \times 5''$, weathered, throated, and grooved, and resting on $14''$ brick-work; a $1\frac{1}{2}''$ window board; the wall rendered inside, and finished at floor with $1\frac{1}{4}''$ torus moulded skirting $9''$ high, scribed to floor.

14. Draw, to a scale of $\frac{1}{6}$, a vertical cross section through a solid window frame, fitted with a $1\frac{1}{2}''$ pivoted sash, $2'$ high, which is to be shown half open.

*15. Give a vertical cross section, to a scale of $\frac{1}{6}$, showing, both in section and elevation, all the details of a $1\frac{1}{2}''$ centre-pivoted swing sash with a $3'' \times 2\frac{1}{2}''$ solid frame set in a $9''$ brick wall. The sash to be $2'\ 3''$ high, and shown half open.

16. Give a vertical section, $\frac{1}{4}$ full size, through both the wood and stone sills of a window opening for a $1\frac{1}{2}''$ swing sash. The stone sill to be $6'' \times 4''$, weathered and throated, and to rest on a $9''$ brick wall. The wood sill to be $4'' \times 3''$, with a $1\frac{1}{4}''$ inside bead, and a $1\frac{1}{4}''$ window board.

CHAPTER XIII

CARPENTRY AND JOINERY

FURTHER POINTS IN THE CONSTRUCTION OF JOINTS

THE joints used in carpentry and joinery have, as far as possible, been treated in connection with the constructional details to which they are particularly applicable. Many joints, as well as some details of construction, still, however, remain to be described.

Principles governing the Construction of Joints.—The principles governing the construction of joints have been laid down by Professor Rankine[1] as follows:—

I. To cut the joints and arrange the fastenings so as to weaken the pieces of timber they connect as little as possible.

II. To place each abutting surface in a joint as nearly as possible perpendicular to the pressure which it has to transmit.

III. To proportion the area of each abutting surface to the pressure which it has to bear, so that the timber may be safe against injury under the heaviest load which occurs in practice, and to form and fit every pair of such surfaces accurately, in order to distribute the stress uniformly.

IV. To proportion the fastenings so that they may be of equal strength with the pieces which they connect.

V. To place the fastenings in each piece of timber so that there shall be sufficient resistance to the giving way of the joint by the fastenings shearing or crushing their way through the timber.

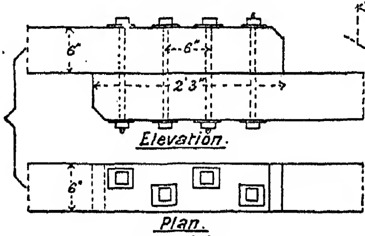
In nearly all cases simple joints are more effective than

[1] *A Manual of Civil Engineering*, by Professor Rankine, p. 454. C. Griffin and Co., 1872.

complicated ones. The latter are not only difficult to fit, but are very liable to be affected by the shrinkage of the timber.

Fastenings.—Pieces of timber may be fastened together by means of nails, screws, bolts, iron straps, keys, wedges, or wooden pins. Square bolts are preferable to round ones.

Fig. 537.



Lapped joint.

Fig. 538.

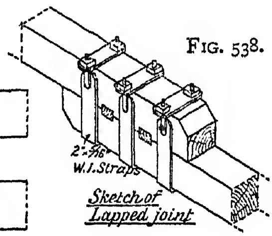


Fig. 539.

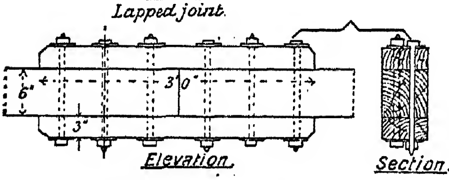


Fig. 540.

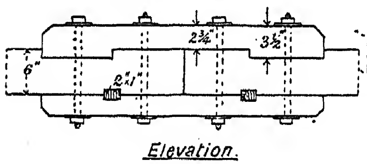
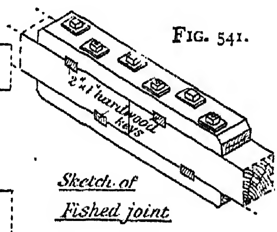


Fig. 541.



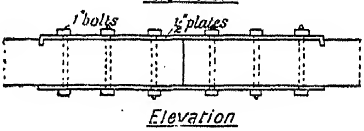


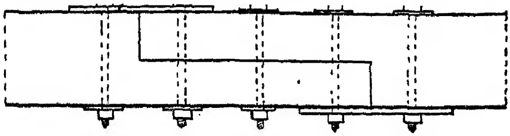
Fig. 542.

Lapped and Fished Joints.

Lengthening of Beams.—It often happens that wooden beams are required longer than they can be obtained in single pieces. The joints used for lengthening such beams may be *lapped*, *fished*, or *scarfed*.

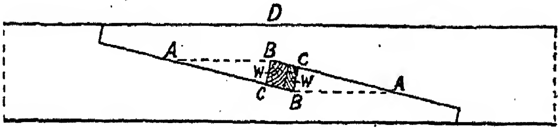
A **lapped** joint is formed when one beam overlaps the other for a certain distance. If the beams are to be subjected to a compression stress, or are liable to a cross strain, iron straps may be used for connecting them (Fig. 538). If the

FIG. 543.



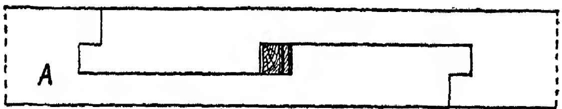
Elevation.

FIG. 544.



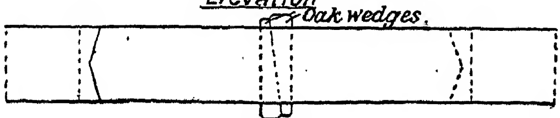
Elevation.

FIG. 545.



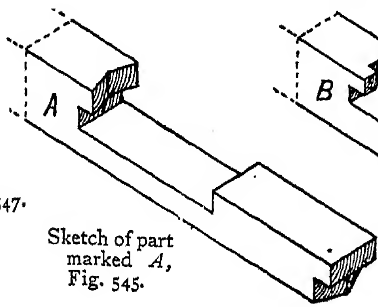
Elevation

FIG. 546.



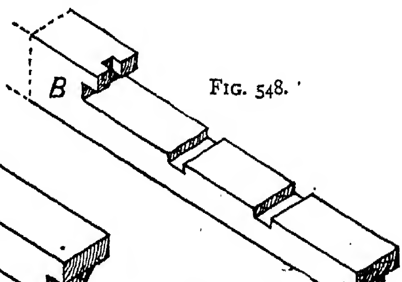
Plan.

FIG. 547.



Sketch of part marked *A*, Fig. 545.

FIG. 548.



Sketch of part marked *B*, Fig. 549.

FIG. 549.

Elevation.

Scarfed Joints.

beam, when in position, will be under the influence of a tension-stress, then bolts are preferable (Fig. 537).

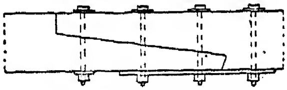


FIG. 550.—Scarfed Joint.

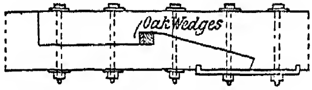


FIG. 551.—Scarfed Joint.

When two beams abut end to end, and the joint is covered with wooden or iron plates secured with bolts, the joint is

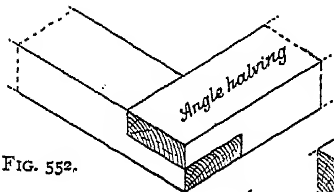


FIG. 552.

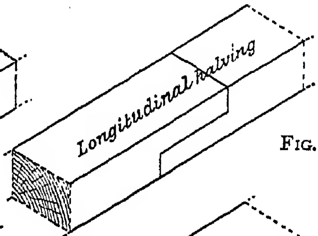


FIG. 555.

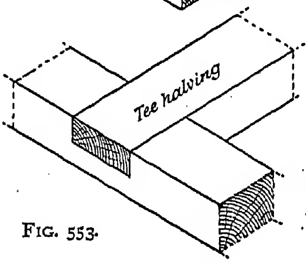


FIG. 553.

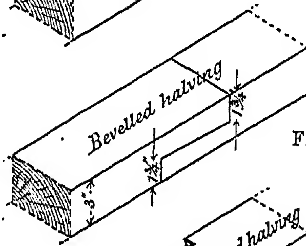


FIG. 556.

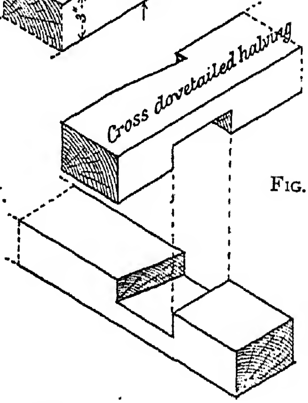


FIG. 557.

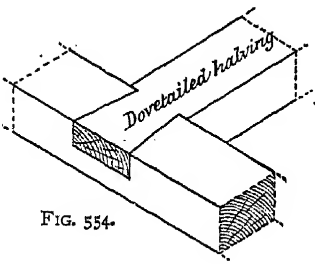


FIG. 554.

Halved Joints.

named a **fished joint**, and the cover plates are called **fish-plates**. With beams "in tension," the fish-plates of wood

may be sunk, or *tabled*, into the main beam, as on the upper edge of Fig. 540; or they may have hard-wood keys driven into trenches formed in both beam and plates as shown in Fig. 541 and on the lower edge of Fig. 540. If iron fish-plates are used, the ends of the plate may be turned into the wooden beam for a short distance. This lessens the stress on the bolts, but reduces the strength of the beam. Care should always be taken that the indentations in the beam are not opposite each other.

The joints just described are all clumsy in appearance, and in many positions would appear very unsightly. The **scarfed joint** is much neater, though not so strong. Figs. 543 to 551 show different forms of the scarfed joint. In the simplest (Fig. 543), each piece is cut away for half its depth, and is secured by bolts. Fig. 544 shows a very common form of scarfed joint used for beams, which, when in position, will be "in tension." The wedges *W*, *W*, of hard wood, are used to tighten up the joint, thus rendering bolts unnecessary. The weakness of this joint lies in the tendency of the triangular pieces *ABC* to shear off. The maximum strength is secured when the length of *AB* is about seven times that of *DB*. Stronger scarfed joints are those shown in Figs. 545 to 551. Such scarfed joints are suitable for beams to be subjected to either tension or compression stresses. The length of the scarf will depend upon the material used; the length may be diminished and the strength of the joint increased by using fish-plates and bolts. Fig. 546 is the plan of the scarf shown in elevation in Fig. 545. Fig. 547 is a sketch of the cut end of one beam of the joint shown in elevation in Fig. 545. Fig. 548 is a corresponding sketch of Fig. 549. Scarfed joints of a design suitable for resisting cross-strain and tension are shown in elevation in Figs. 550 and 551.

Halving.—When, as with wall-plates, for example, two pieces are so connected that their surfaces are flush, each piece being cut away at the joint to half its depth, a **halved joint** is obtained. Figs. 552 to 557 show different forms of halved joints, with their distinctive names indicated.

Mortise and Tenon Joint.—This joint, which is of more general application than any other, has already been described in some detail on pp. 170 and 171. The tenon is

usually made about one-third the thickness of the framing, as shown in Fig. 458. The tenons in this figure are haunched (p. 171). In the tusk tenon (Fig. 214) this proportion is not adhered to, as it would weaken the beam or joint too much. The *stump tenon* and the *double tenon* have also been previously described (Figs. 459 and 458).

The joint shown in Fig. 558 has what is known as a *cross-tongue* on each shoulder in addition to the tenon. This method of strengthening the joint may be used in all cases where the tenon cannot be conveniently constructed of the proportions given. Cross-tongues are cut out of hard wood in such a way

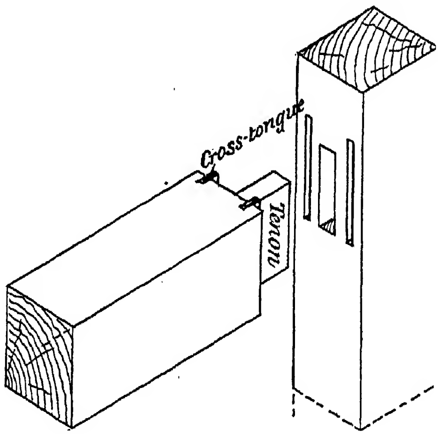


FIG. 558.—Mortise and Tenon Joint with Cross-tongues.

that the grain of the tongue runs in the same direction as that of the rail.

In order to give additional strength to the joint, the end of the piece bearing the tenon is itself also frequently sunk, or *housed*, into the other piece for a short distance. This arrangement is known as a *mortised and housed joint* (Figs. 559 and 560).

Fox-wedging.—Fox-wedging is a device adopted for securing a mortise and tenon joint in cases where the joint cannot be wedged from the outside, as, for example, in the case of a post fixed against a wall, or of a sill resting on a floor. In these and similar contingencies the mortise is cut wider

inside, and saw-cuts are made in the end of the tenon. Wedges are then inserted in the cuts, and when the rail is driven home the wedges spread the outer end of the tenon (Figs. 561 and 562).

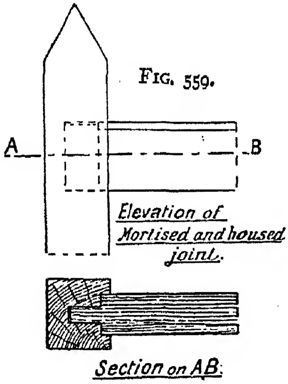


FIG. 559.

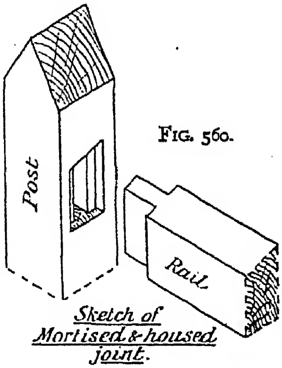
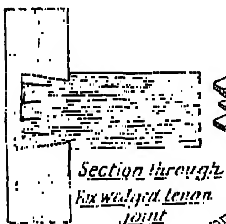


FIG. 560.

FIG. 561.



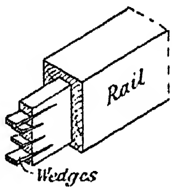


FIG. 562.

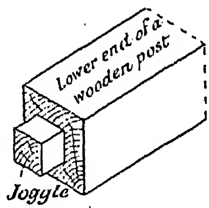


FIG. 565.

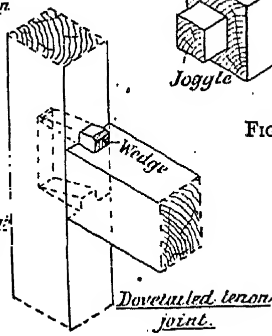


FIG. 563. FIG. 564.

This method of fox-wedging is also suitable for superior work, where the appearance of the end of the tenon on the edge of the framing would be considered objectionable.

Dovetailed Tenon.—In the dovetailed tenon joint one

edge of the tenon is cut obliquely (*splayed*), and the mortise is made a little wider than the width of the tenon. The joint is secured by means of a wedge which is driven into the space left on the straight side of the tenon (Figs. 563 and 564).

Bridle Joint.—The bridle joint is the converse of the mortise and tenon joint. In bridle joints the middle part of one member is made to fork on to the other member, which is suitably cut to receive it (Fig. 259).

Joggle Joint.—In a joggle joint a projection—the *joggle*—is left on the lower end of a wooden post which is intended to fit into a stone or wooden sill. The sill itself contains a suitable mortise cut to receive the joggle (Fig. 565).

Centres.—Whenever arches of brick or stone are built, it is necessary to temporarily support them, and this is effected by constructing them on wooden centres. The upper surface of the centre corresponds in outline to that of the intrados (p. 23) of the arch. Figs. 566 and 567 show the elevation and

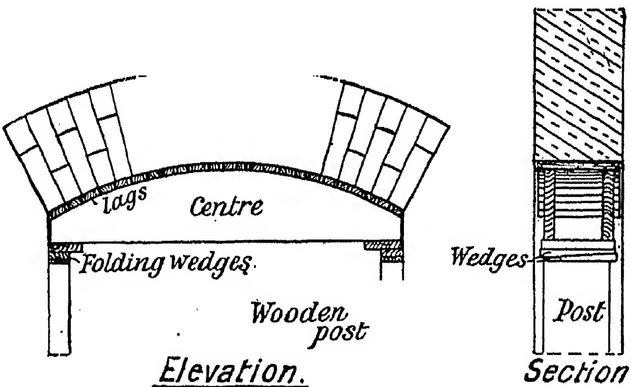


FIG. 566.

FIG. 567.

Wooden Centre for a Segmental Arch, showing a few of the Arch Bricks in position.

section of a centre for a segmental arch of the simplest kind. The centre consists of two parallel boards, *a* and *b* (Fig. 569), having their upper edges cut to the required curvature, and connected throughout their curved length by narrow wooden strips (*lags*) for supporting the bricks of the arch. The length of the lags, and the distance apart of the two boards to which they are nailed, depend upon the thickness of the

walls. The length of each lag should be at least half an inch ($\frac{1}{2}''$) less than the thickness of the wall, for in this way the bricklayer's "guide-line" will not be interfered with. All centres should be so fixed that they can easily be loosened or removed as soon as the arch is finished, thus allowing any slight irregularity in the brick-work to adjust itself. This object is

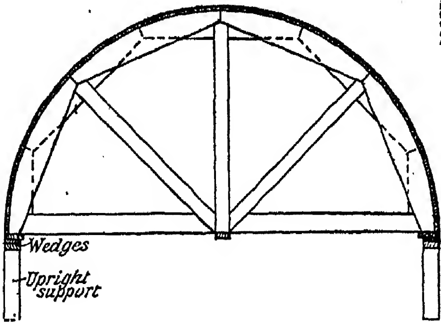


FIG. 568.
Elevation of Centre for a Semicircular Arch.

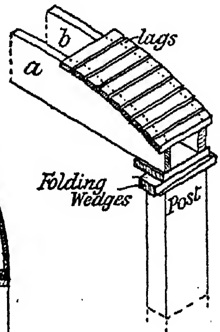


FIG. 569.
Sketch of Part of Wooden Centre shown in Elevation in Fig. 566.

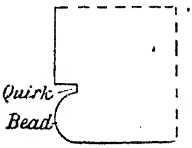
secured by supporting the centre on upright wooden posts, on the top of each of which a pair of folding wedges is inserted. These wedges can be slightly eased when necessary. Fig. 569 is a sketch of part of a centre of the kind described, with the wedges in position. Fig. 568 is the elevation of a centre for a semicircular arch of larger span. As the illustration makes quite clear, it is built up of several pieces.

JOINERY

Joinery.—Most of the foregoing remarks upon joints, except those dealing with the mortise and tenon joint, are more particularly applicable to carpentry. While carpentry may be considered to embrace the framing together of the rougher timbers used in the construction of a building, joinery is especially concerned in finishing such finer work as doors, window-frames, staircases, cupboards, etc. The distinction between the two may be said to consist in the use of the

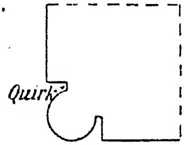
plane. The timber used for joiners' work requires to be more thoroughly seasoned than is necessary with that used for

FIG. 570.



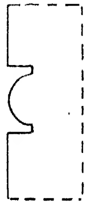
Single quirked Bead

FIG. 571.



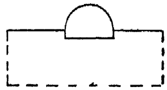
Double quirked Staff bead

FIG. 572.



Double quirked flush bead

FIG. 573.



Cock bead

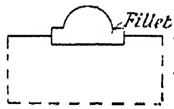


FIG. 574.

Cock bead & fillet

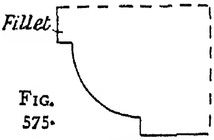


FIG. 575.

Roman Ovolo

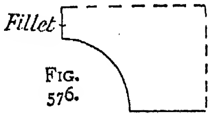


FIG. 576.

Cavetto or Hollow

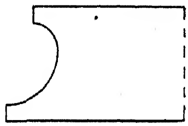


FIG. 579.

Scotia

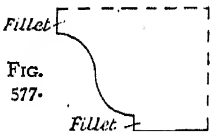


FIG. 577.

Ogee or Cyma r.

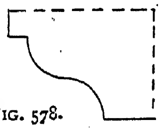


FIG. 578.

Reverse Ogee or Cyma reversa.

FIG. 580.

Torus mould.

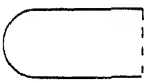
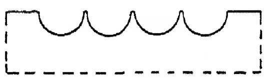


FIG. 581.

Rounded Nosing

FIG. 582.

FIG. 583.



Fluting

FIG. 584.

carpentry. Much of the material for joiners' work is now prepared by machinery.

Edges Shot.—Boards having their edges planed straight and true are said to have their edges shot.

Chamfering.—When the arris (corner) of a board is taken off, as shown in Fig. 448, it is said to be *chamfered.* If the chamfering does not extend to the ends of the board, but is "stopped," as in Fig. 462, the edge is said to be *stop-chamfered.*

Nosing.—This term is applied to the edge of a board which overhangs a vertical surface, as, for example, the inside window-board (Fig. 526) or the treads of the steps of a wooden staircase. If the overhanging edge is semicircular in section (Fig. 581), it is called a *rounded nosing.* Fig. 582 is a section of a *moulded nosing.*

Mouldings.—The arrises of joiners' work are often ornamented by mouldings. The curves in Roman mouldings are segments of circles, while in Greek mouldings parabolic and elliptical curves predominate. Roman mouldings are built up from the types shown in Figs. 570 to 580. The distinctive name is in each case indicated on the sketch.

Bead or Astragal.—Various forms of this moulding are shown in Figs. 570 to 574. The difference between *quirked bead* (Fig. 570) and *double-quirked or staff bead* (Fig. 571), and between *flush bead* (Fig. 572) and *cock bead* (Fig. 573), should be particularly noticed. The bead is extensively used at the joints of boarding, to counteract the unsightly appearance that might be caused by any slight shrinkage. When a number of flush beads are worked together on the same surface, as in Fig. 583, a *reeded moulding* is obtained. *Fluting* (Fig. 584) is the converse of reeding.

Torus.—In this moulding (Fig. 580) the diameter of the bead is vertical. It is surmounted by a flat projecting part called a *fillet.*

Mitring and Scribing.—When two lengths of the same moulding meet at an angle, as, for example, at the corners of the architrave (p. 184) surrounding a door or window opening, or in the moulding round a door panel, the line of the joint always bisects the angle, and the joint is called a *mitred joint* (Fig. 586). Under certain conditions, it is better to cut the end of one moulding to fit the profile of the other, as shown in Fig. 587. This plan is called *scribing.* Other examples of these two joints are found in the skirting board which runs round a room. The external angles, as at *X* (Fig. 609), would

be mitred. The internal angles, as at *Y*, are scribed. The method of cutting the lower edge of a skirting board to fit the

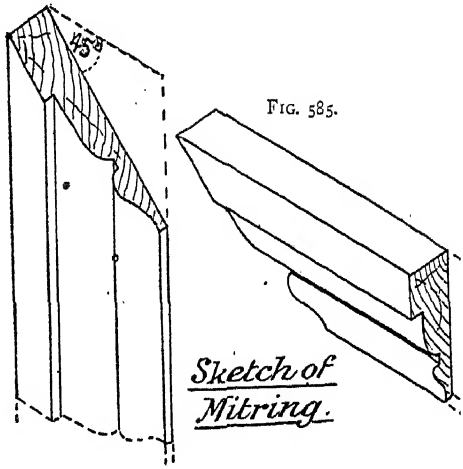


FIG. 585.

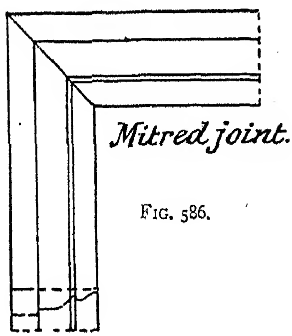


FIG. 586.

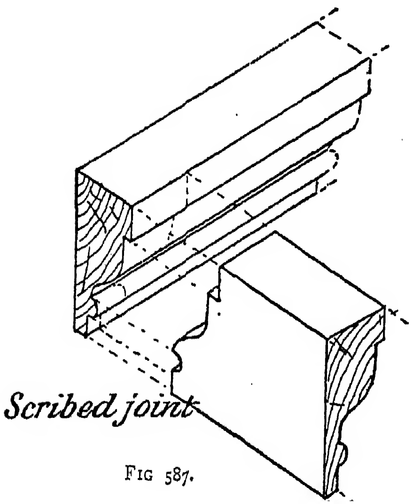


FIG 587.

slight irregularities of the floor (instead of tonguing the board into the floor) is also known as scribing.

Match - boarding. — Timber, however well seasoned, always has a greater or less tendency to shrink; and this fact

renders it inadvisable to use wide boards in covering surfaces of large area. In superior work panelled framing—similar in character to that used in doors—is extensively adopted. A convenient alternative method is, however, to use boards of batten width, with tongued-and-grooved or rebated edges. This class of boarding is known as *match-boarding*. In Fig. 589, which is a cross section of such tongued-and-grooved battens, the tongued edge of each board is beaded. This bead serves the double purpose of destroying the monotony of the surface, and of hiding any slight shrinkage that may take

FIG. 588.

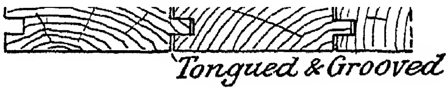
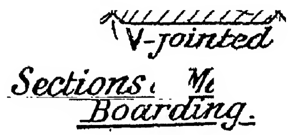


FIG. 589.

FIG. 590.



place in the boards. It is evident that if some such means of treating the joint were not adopted, as is the case in Fig. 588, a slight shrinkage would produce an unsightly appearance. Instead of being beaded, the edges are often chamfered as in Fig. 590. This treatment is known as *V-jointing*. Examples of the use of match-boarding are seen in wainscotting, and also in boarded ceilings. Wide panels in framing are also often constructed of match-boarding.

Keying.—The panels used in framing, as well as thin wide boards which are liable to warp, are sometimes strengthened by the insertion of tapering *dovetailed keys* of hard wood. These are placed at right angles to the grain of the wood of

the boards, as shown in Fig. 591. Another form of key is known as the *hammer-headed key*. Fig. 592 shows its application in connecting the jamb and curved head of a door or

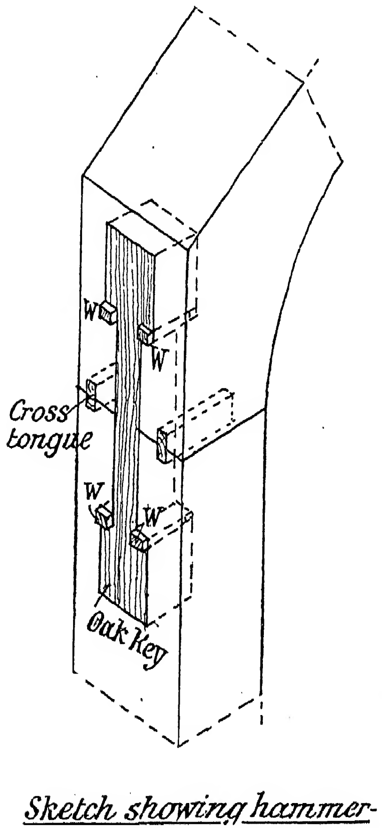


FIG. 592.

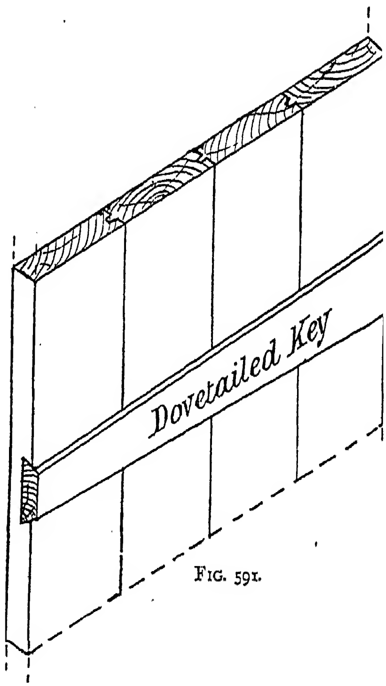


FIG. 591.

solid window-frame. The wedges *W* are driven in to tighten the joint.

Angle Joints.—Fig. 593 is a cross section showing the simplest joint for connecting together two boards meeting at an angle. Figs. 594 to 596 show variations of the same joint.

Figs. 597 to 600 are sections through different forms of *trenched* joints. The first of these (Fig. 597) might also be called a

FIG. 593. FIG. 594. FIG. 595. FIG. 596.

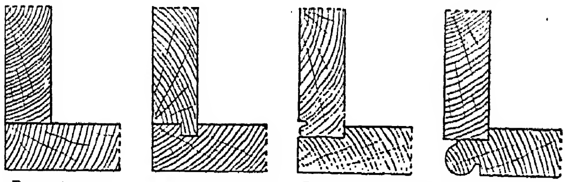
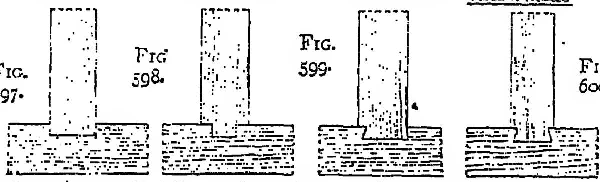


FIG. 597. FIG. 598. FIG. 599. FIG. 600.



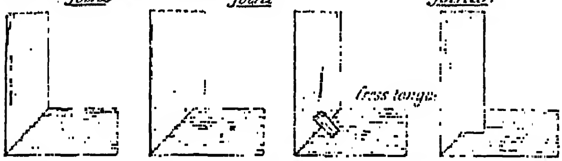


FIG. 601. FIG. 602. FIG. 603 FIG. 604.

housed joint. In cases where it is undesirable to show the end grain of the wood, mitring is resorted to. Figs. 601 to 604 are sections through various kinds of mitred joints.

Cross-grooving.—The joint shown in section in Fig. 594 may also be applied in the manner shown in isometric projection in Fig. 605, as, for example, at the corners of boxes or cisterns. The groove into which the tongue fits is, when it runs across the grain of the wood, an example of *cross-grooving*.

Dovetailing.—Figs. 599 and 600 are sections of dovetailed joints. Fig. 606 is a sketch of the common form of dovetailed joint used in joinery. This is, in fact, the strongest kind of angle dovetailed joint. It can only be used, however, when

there is no objection to the end grain of the wood being visible. The *lap dovetail* (Fig. 607) is so arranged that the

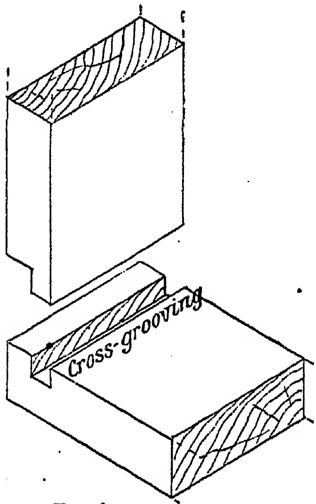


FIG. 605.

joint is not visible on one side. It is useful in such work as the construction of drawers. The *mitred or secret dovetail*

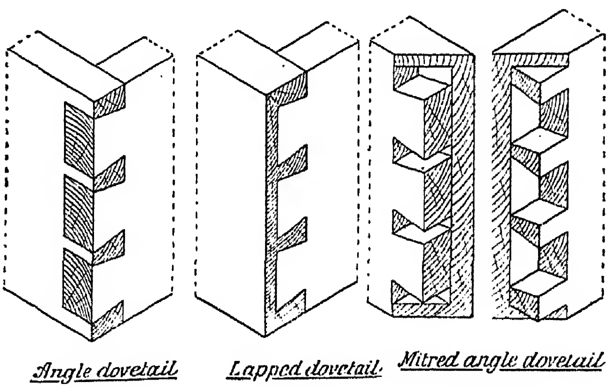


FIG. 606. FIG. 607. FIG. 608.

(Fig. 608) is not so strong as either of the others; but is used when it is desired to completely hide the joint.

Fixings.—Joiners' work is fixed to the masonry or brickwork by methods which vary according to the class of building. If the finished woodwork is placed in position before the walls and the plaster are dry, the timber will swell, and, after drying, it will be apparent that the joints have been strained. On this account, therefore, the joiners' work should, as far as possible, be left unfixed until the building is dry, and then attached to the rough wooden grounds which have formed a guide for the plasterers' work. These grounds are either nailed to wooden nogs or slips built into the wall, or to plugs driven into the joints between the bricks. Iron holdfasts are

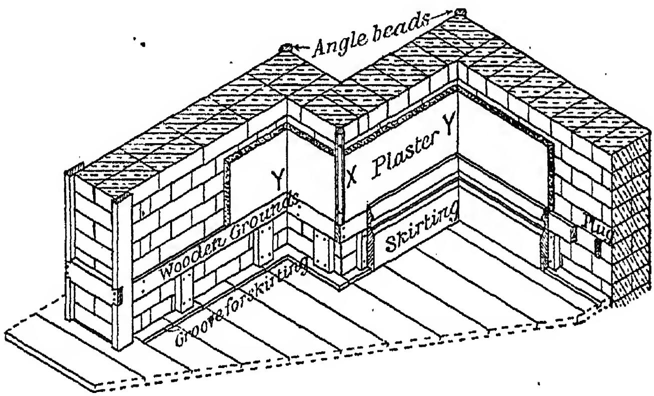


FIG. 609—Angles in a Room showing method of fixing Skirting, Grounds, Angle Beads, etc.

sometimes used for securing these grounds, especially around chimney-flues. Fig. 609 shows how the grounds are fixed in part of a doorway, and also behind the skirting boards. Figs. 611, 612, and 613 are sections through three different forms of skirting boards. The one illustrated in Fig. 613 is known as a *torus-moulded skirting*, and is shown scribed to the floor. Figs. 611 and 612 are examples of *moulded skirting;* they have their lower edges tongued into the floor. The former is called a *double-faced skirting*.

Angle Beads.—When an external angle occurs in a room, as at X in Fig. 609, an **angle or staff bead** is fixed by means of wooden plugs to the wall, as a guide for the plasterer as well as to protect the angle. Fig. 610 is a horizontal section

of an angle bead. The bead is sometimes dispensed with, and the plasterer works the angle in cement.

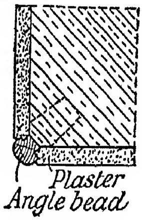


FIG. 610.

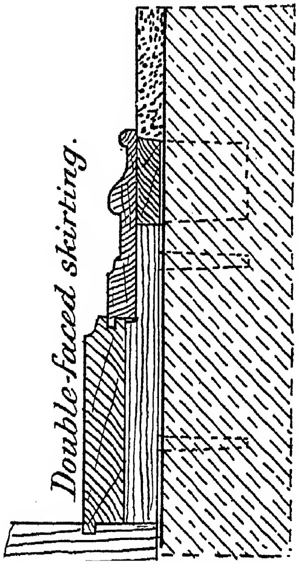
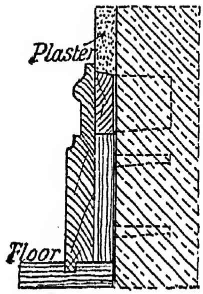
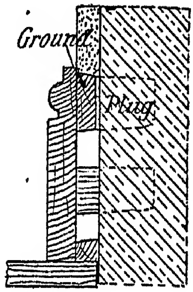


FIG. 611.



Moulded Skirting tongued to Floor.

FIG. 612.



Section through toru Moulded Skirting.

FIG. 613.

EXAMINATION QUESTIONS ON CARPENTRY AND JOINERY

*1. *AA* and *BB* are the ends of timber beams to be jointed together. Draw, to a scale of $\frac{3}{4}''$ to a foot, showing at *AA* a butt

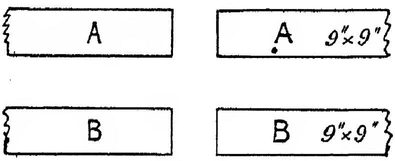


FIG. 614.

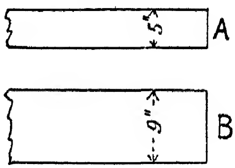


FIG. 615.

joint with timber fish-plates; and at *BB* a scarfed joint to take compression, secured with iron fish-plates (Fig. 614).

*2. *A* is the plan and *B* the elevation of the end of a timber balk.

Show, at *A*, two such balks connected by $\frac{1}{2}''$ iron fish-plates, and at *B* by halving, to a scale of $1\frac{1}{2}''$ to a foot (Fig. 615).

*3. Sketch, showing the end of a beam to be connected with a similar one by an ordinary scarfed joint (Fig. 616).

Give a plan and elevation of the joint to a scale of $1''$ to a foot.

*4. Elevation, showing two $13''$-square balks of timber halved together (Fig. 617). Draw the joint, to a scale of $\frac{3}{4}''$ to a foot,

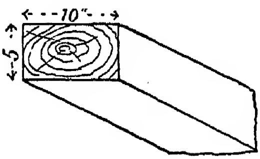


FIG. 616

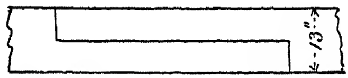


FIG. 617.

FIG. 618.

but showing it tabled and secured by hard-wood wedges, without any bolts.

*5. A joint in a timber tie-beam (Fig. 618).

Draw, to a scale of an inch to a foot, making any addition or alteration you think necessary to ensure a secure joint, and give the name of the joint.

Draw a similar joint, capable of resisting both direct tension and compression.

*6. Section of a beam which is to be lengthened by a scarfed joint, without any fish-plates or bolts (Fig. 619).

Give, to a scale of $\frac{1}{12}$, elevations of two forms of joint—

(*a*) Supposing the beam to be exposed to tension only.

(*b*) Supposing the beam to be exposed to both tension and compression.

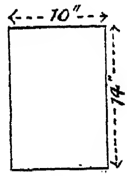


FIG 619.

7. Give drawings to a scale of $\frac{1}{12}$, explaining fully the following details :—

A butt joint, the timber being $9'' \times 9''$, and secured by $\frac{1}{2}''$ iron fish-plates.

The foot of a $12'' \times 12''$ wooden story post mortised into a stone base $16'' \times 16'' \times 12''$; the top of the base to be chamfered.

*8. *A* represents the ends of two wall-plates at the angle of a building, to be halved together (Fig. 620).

B represents the end of a wall-plate on a cross-wall, to be bevel-halved on to a main wall-plate.

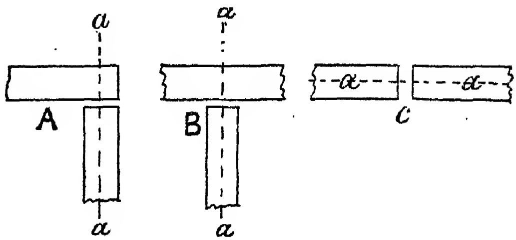


FIG. 620.

C represents the ends of two wall-plates to be connected by scarfing.

Draw, $\frac{1}{8}$ full size, the sections *a—a* through the finished joints; showing $4\frac{1}{2}'' \times 3''$ plates in each case.

9. Give sketches explaining the following terms in carpenters' work :—

Plain fished joint—cogged joint—stump tenon.

10. Show by sketches the meaning of the following terms in carpenters' work :—

Bird's-mouth—mortised and housed—dovetail halving.

11. Show by sketches the meaning of the following terms :—

Match-boarding—Mortise and tenon—Haunched tenon.

State the object of the latter.

* 12. The head of an oak gate-post, and the end of a rail which is to be housed, mortised, and fox-wedged into it (Fig. 621).

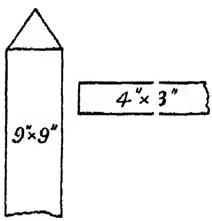


FIG. 621.

Draw, to a scale of $\frac{3}{4}''$ to a foot, showing all the details of the joint before connecting up. The post to be shown in section.

13. Show by sketches the meaning of the terms "fox-wedging" and "chase mortise."

14. Give an elevation and central cross section, to a scale of 2′ to an inch, showing the centering you would use in turning a flat segmental gauged brick arch over a 4-foot window-opening, and a semicircular rough brick arch, 3 feet deep, over a 9-foot span. Give the names of the different parts. The arches to be shown, but the joints of the brickwork need not be filled in.

15. Explain by sketches, or otherwise, the following terms :—

Edges shot—ploughed, tongued, and V-jointed—mortised and housed.

16. Draw, to a scale of $\frac{1}{3}$, a cross section of—

A 3″ deal with one edge chamfered and one edge beaded.

A 2″ batten tongued and grooved.

17. Show by sketches the meaning of the following terms in carpenters' work :—

Cross-grooving; cock bead; mortising and housing for rails, as applied to the head of a timber post; panelled square and flat, and moulded one side.

18. Explain by sketches the following terms :—

Return or staff bead.

Rebated and beaded boards for partition.

Shouldered or tusk tenon.

* 19. Cross section of four battens 5″ × $1\frac{1}{2}$″ (Fig. 622).

Draw, $\frac{1}{3}$ full size, showing a rebated and beaded joint at *A*; a ploughed and tongued joint at *B*, suitable for floor-boards; and a rebated and filleted joint at *C*, for the same purpose.

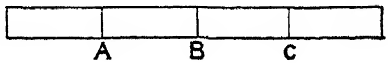


Fig. 622

Miscellaneous Examination Questions

*20. *A* is the section of a wall-plate carrying the end of a joist. Draw to the same scale, showing the joist cogged down to the plate.

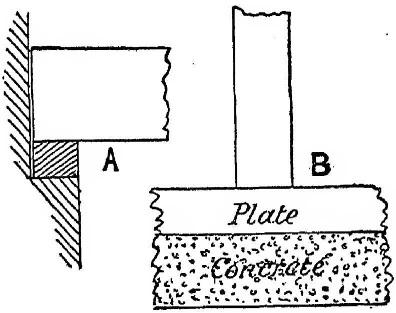


Fig. 623.

B is the foot of a wooden upright, secured by fox-wedging to a wood sill sunk in a concrete floor (Fig. 623).

Draw to the same scale, showing the details of the joint, in section.

21. Show clearly, by sketches, the meaning of the following terms :—

Match-boarding.
Flush bead.
Lead tingle.
Doubling eaves course.

22. Explain, by aid of sketches, the meaning of the following terms :—

Wood plugs, lead dots, double-quirked bead, wood lintel.

23. Explain, by sketches, the meaning of the following terms :—

Joggle joint.
Spandrils of arches.
Lead plug.
Step flashing.

24. Give sketches showing the meaning of the following terms :—

Spandrils of an arch.
King-closer.
Pole-plate.
Channel iron.

25. Give sketches explaining the use of the following :—

Lead tingles.
Tile creasing.
Stone corbels.

CHAPTER XIV

MATERIALS

Lime.—The lime used for building purposes is obtained from limestone, which is *calcined*, that is, burnt or heated to redness in kilns—the object being to drive off the carbon dioxide and moisture. Lime is divided into three classes, according to its purity, which is dependent upon the purity of the limestone from which it is obtained.

Pure, *Rich*, or *Fat Lime.*—This is obtained from a limestone consisting of practically pure carbonate of lime, such as chalk and some kinds of marble. In slaking, rich lime increases from two to three and a half times in bulk, becoming very hot, and giving off much steam. The want of setting power in such "fat" lime renders it unsuitable for building purposes, except for internal plastering, whitewashing, etc. It is much used in the manufacture of artificial cement.

Poor Lime.—Poor lime is derived from limestone containing from 60 to 90 per cent. of carbonate of lime, together with useless impurities, which do not, however, affect the setting power of mortar made with it.

Hydraulic or "Stone" Lime.—Hydraulic lime usually contains a considerable proportion of clay. This admixture of clay is very valuable, as it gives the mortar the property of setting in water, or in damp situations. The setting power of such hydraulic mortar is proportional to the amount of clay present in the lime, which varies from 5 to 30 per cent. Hydraulic lime is difficult to slake by the addition of water, and is therefore often simply ground to a fine powder before the mortar is mixed. Its hydraulic properties render it particularly suitable for making the mortar used in the construc-

tion of foundations and the walls of buildings. It ought never to be used for internal plastering, as, owing to the difficulty of slaking, it is liable to contain small unslaked particles, which eventually swell and damage the surface of the plaster. Some of the best hydraulic limestone is obtained from the geological strata making up the Lias formation, the resulting lime being known as *Lias lime*.

Cements.—Cements may be classed as (1) natural; and (2) artificial. They differ from limes in not slaking or breaking up when mixed with water. They are used in the making of concrete and cement mortar for foundations and other important structures, as well as for various kinds of plastering.

Roman Cement.—This is a natural cement obtained by calcining certain stones (septarian nodules) found in the London Clay. These nodules contain from 30 to 45 per cent. of clay, the remainder being chiefly carbonate of lime. Before being burnt, the septaria have a fine close grain, a pasty appearance, and a greasy surface when broken. Good Roman cement is generally of a rich brown colour; it weighs about 75 lbs. per bushel, sets quickly, but does not attain any great strength. It should be kept in air-tight casks. Its use is chiefly confined to temporary work where quick setting is of more importance than strength. Roman cement is, however, to a large extent, being superseded by Portland cement.

Portland Cement.—Portland cement derives its name from its resemblance in colour to Portland stone. It is now more extensively used than any other cement. It is generally made by mixing together chalk or limestone and clay. The mixture is first dried over ovens, and is then burnt in kilns, and, lastly, ground to a very fine powder. It should in its final form contain about 60 per cent. of lime, 21 per cent. of soluble silica, and about 10 per cent. of alumina. The colour of the best Portland cement is greenish gray, and its weight is about 112 lbs. per bushel. The cement is tested by forming it into small blocks or *briquettes*, and keeping these in water for seven days. At the end of that time they should be able to withstand a tensile stress of 350 lbs. to the square inch. Portland cement should, before being used, be exposed to the air for three or four weeks in a dry place, and be occa-

sionally turned over. This treatment allows time for the lime in it to become completely air-slaked and cooled. The cement also increases in bulk during the exposure.

Concrete.—Concrete is a mixture of mortar with pieces of such hard material as broken stones, bricks, slag, etc. The mortar is composed of either lime or cement, and sand. The composition of concrete varies according to the class of work for which it is used.

Cement concrete suitable for the foundations of a building may be obtained by mixing one part by measure of Portland cement, two parts of clean sharp sand, and six parts of broken stones which will pass through a two-inch ring. For floors, roofs, etc., a mixture of one part of Portland cement, one part of sand, and four parts of broken stones which will pass through a three-quarter-inch ring is suitable. The materials are first mixed together in the dry state, and water is then added gradually until a plastic mass is obtained. The concrete should be laid as soon as it is mixed, being beaten during deposition to increase its solidity. Any junction of previously laid concrete with new deposits should be well wetted; moreover, the strength of the material is increased if the whole is kept damp for a few days after laying.

Mortar.—Mortar is a mixture of sand with either lime or cement: sufficient water being added to form a pasty mass. The sand should be free from vegetable matter, and of a sharp gritty nature. For ordinary building purposes, one part by measure of hydraulic lime to one and a half or two parts of sand may be used. For internal plasterers' work, a suitable mortar is obtained by using one part of "fat" lime to three parts of sand. The toughness of mortar used for plastering purposes is increased by adding clean ox-hair.

Bricks.—Clay is the chief material from which bricks are made, but it is often necessary to mix the clay with sand to counteract its tendency to warping. The presence in the clay of a little limestone *in very small particles* improves the quality of the bricks, but clay containing lumps of limestone larger than a pin's head ought not to be used, as, during the burning of the bricks, the limestone is converted into quicklime, which, on exposure to damp, bursts and splits the bricks.

It is best to dig the clay in the winter, and expose it to the disintegrating action of the weather for some months.

The methods of brickmaking differ in various localities and according to the nature of the clay. Generally, the clay is made plastic by the addition of water, and moulded into blocks. These blocks are then dried by being first spread on a floor and afterwards stacked, and are finally burnt in kilns. A good brick is hard, gives a ringing sound when struck with another one, is of a cherry-red colour, is free from cracks, is of regular shape, and has straight arrises. It should not absorb more than 12 per cent. of its weight when soaked in water.

Building Stones.—Several different kinds of stone are used for building purposes. The commonest are sandstones, limestones, and granites. Of these, sandstones and limestones are generally *laminated*, that is, they occur in layers. When used in buildings, they should be laid so that the "natural bed" (p. 33) of each stone is at right angles to the pressure put upon it.

Sandstones.—Sandstones are composed of grains of quartz, cemented together by silica, oxide of iron, carbonate of lime, or other substances. As quartz is practically unaffected by the weather, the weathering properties of a sandstone are determined by the nature of the cementing material. Sandstones vary in texture, from the coarse-grained rock known as millstone grit to the varieties in which the grains are almost indistinguishable. The best-known sandstones are obtained from Yorkshire, Forest of Dean, Mansfield, and the neighbourhood of Edinburgh. The last-named, known as Craigleith stone, is considered the most durable. It contains 98 per cent. of silica.

Limestones. — Limestones vary greatly in texture and hardness, from the friable rock known as chalk to hard marble. Building limestones are mainly composed of carbonate of lime. The limestone known as *dolomite* contains about 40 per cent. of carborate of magnesia. Many limestones are very soft when first quarried, but harden on exposure. The commonest kinds are Bath stone, Portland stone, Kentish rag, and yellow Mansfield. *Marble* is practically pure carbonate of lime in a crystalline form. It is sufficiently hard and compact

to take a fine polish, and is therefore used for columns, carvings, and ornamental work generally.

Granite.—Granite consists typically of quartz, felspar, and mica. It is used chiefly for heavy engineering works, such as bridges, docks, lighthouses, etc., and also for paving. On account of expense, it is used for ordinary buildings only in granitic neighbourhoods. It is often, however, employed for such ornamental features as columns, pilasters, heavy plinths, etc. The Scotch granites are especially distinguished for their beauty and durability. Polishing improves their weathering properties as well as their appearance.

Building stones are generally softer when first quarried, as they contain a certain amount of moisture named "quarry sap," which eventually dries out. The weathering properties of the stone are improved by the drying process, but the difficulty of working is thereby increased.

The following tests will, in general, show whether a stone is likely to prove durable:—

1. Examine a new fracture through a powerful lens. The grains should be sharp, clean and bright; a dull earthy appearance indicates early decomposition.

2. When immersed in water for twenty-four hours, a good building stone will absorb less water than an inferior one.

3. Knock off a few small pieces and immerse them in a glass of water; let them remain undisturbed for some time, then agitate gently. With a good stone the water remains clear. If the water becomes turbid, the stone is liable to weather badly.

4. Examine old buildings of the kind of stone under consideration, particularly noticing the arrises.

It should be noted that a stone which is very durable in one locality may decay in another. For example, limestones are more affected by the air of towns than by country air.

The weight of building stone varies from 120 to 180 lbs. per cubic foot, and averages about 150 lbs.

Slates.—A good slate should have the following properties: It should be tough and hard, and give a ringing sound when struck. The grain should be fine, and should run in the direction of the length of the slate. The slate should not increase appreciably in weight when immersed in water, and if partly immersed, the exposed portion should not show signs of any

moisture. When breathed upon, the slate should not give off a clayey odour.

The finest slates are obtained from Wales. These are generally of a bluish tint. Westmoreland slates are thicker than Welsh slates, and are greenish in colour.

Iron and Steel.—Cast iron, wrought iron, and steel are obtained from pig-iron, the unpurified metal extracted from iron ores. The difference between them lies chiefly in the amount of carbon present. Cast iron contains from 2 to 6 per cent., whereas wrought iron, when pure, is free from carbon. In practice, however, wrought iron contains a small quantity (not more than 0.25 per cent.) of carbon. Steel contains from 0.15 to 2 per cent.

Cast Iron.—As explained on p. 51, cast iron is much stronger in compression than in tension. It is used for pillars, girders, truss connections, eaves-gutters, rain-water pipes, etc. Cast iron is generally obtained in the foundry by remelting pig-iron and running it into moulds of the required shape. Occasionally, however, the iron is moulded as it comes from the blast-furnace, but is of better quality if remelted in a cupola. A little limestone is added to the iron before remelting; this acts as a flux, and also combines with certain impurities present in the pig-iron, separating these in the form of slag.

Cast iron improves in quality at each remelting up to about the fourteenth time. It is then more than twice as strong as after the first remelting. Gray cast iron contains more carbon than the white variety. The latter is very hard and brittle, and is almost useless for castings which have to withstand any considerable stress. Cast iron is of a crystalline texture, and cannot be welded.

Wrought Iron.—Wrought iron is prepared from pig-iron by a series of processes by which the carbon is wholly, or very largely, eliminated, and the crystals are converted into fibres. Various impurities (phosphorus, silica, etc.) which cause the brittleness of pig-iron are at the same time removed. These processes consist of refining, shingling, and rolling. The fibrous texture which gives wrought iron its marked tensile strength (p. 54) is imparted in the rolling process: the tensile strength being increased at each rolling up to the fifth time.

Iron which has been rolled once only is known as *puddle bar.* It is the most inferior quality of wrought iron. *Merchant bar* iron is produced by reheating and rolling together short lengths of puddled bar. Even this quality is inferior, and cannot be easily forged. The quality known as *best bar* is prepared in a similar manner from merchant bar.

The stresses which good wrought iron should be able to withstand have been mentioned on p. 54. It should also be ductile, that is, able to stretch before giving way. The best qualities will stretch 20 per cent. before breaking. A good test for wrought iron is to see to what extent it can be bent without breaking. Good rivet iron will bend double without signs of fracture.

The appearance of the fractured surface of good wrought iron depends upon the nature of the test. If the fracture is caused by a slowly applied tensile stress the surface will be fibrous in appearance, with a diminution of the area caused by the stretching of the metal. A crystalline appearance generally results at the fracture if this is caused by a suddenly applied tensile stress.

Steel.—As regards the proportion of carbon present, steel is intermediate between cast iron and wrought iron. It is now extensively produced from pig-iron by what are known as the "Bessemer" and "Siemens-Martin" processes respectively.

The *Bessemer process* consists in first oxidising the impurities present in the pig-iron by blowing a blast of air through the molten metal, and then adding the amount of white cast iron required to give the necessary proportion of carbon.

Siemens-Martin steel is made by melting pig-iron in a reverberatory furnace, and then adding certain kinds of ore containing the amount of carbon necessary to produce the description of steel required.

Another method of manufacturing steel is the *cementation process.* This consists in heating bars of the purest wrought iron with broken charcoal for several days to a red heat. The steel thus obtained is known as *blister steel.* By hammering and rolling, it is converted into a variety known as *shear steel,* which is chiefly used for tool-making.

Through the recent improvements in manufacture, steel

is now largely taking the place of wrought iron in the construction of buildings, especially for girders, roof trusses, etc.

Steel is about 20 per cent. stronger both in tension and compression than wrought iron.

Timber.—The wood used in building construction is obtained from the trees known to botanists as *exogens*, to which group all our great forest trees belong.

Structure.—An examination of the cross section of any such tree shows that it consists of a number of concentric layers named *annual rings* enclosing a central pith, and surrounded by the bark. The layers are called annual rings because, under ordinary conditions, one is formed each year. Radiating from the pith to the bark is a series of lines known as *medullary rays.* In many kinds of wood these are not visible to the naked eye.

Felling.—The oak and many other hard wood trees are best cut down at an age of from 120 to 200 years. Soft wood trees, such as the firs and pines, are ready for felling at from 70 to 100 years old. The best time of the year for felling is in the early winter months, when the sap is at rest. If the tree is cut during the spring or early autumn the sap affects the durability of the wood.

Converting.—As an average tree when cut down contains from 20 to 30 per cent. of moisture, it should at once be so sawn or "converted" that the shrinkage on drying will not split the wood. If the tree is left unsawn, the outer layers dry first and cause splitting to take place in a radial direction. To obviate the loss of timber that might be thus caused, the tree should be at once either cut into planks, or quartered, that is, be sawn by two radial cuts at right angles to each other. The latter method is almost always adopted in the case of such hard-wood trees as the oak, as by this means the beautiful marking known as *silver grain* is preserved.

Seasoning.—As above explained, a large proportion of moisture is present in timber when it is felled. As this moisture dries out the wood contracts, and therefore requires to be exposed to the air, or seasoned, for some time before it can be satisfactorily used for constructional purposes. The best method of seasoning is by stacking in such a manner

that the air can circulate freely all round each piece. This is named "natural seasoning," and requires a considerable time, varying with the thickness of the planks and the kind of wood. Other methods are often adopted, but with less satisfactory results. Timber is considered to be sufficiently seasoned for carpenters' work when it has lost about one-fifth of its weight. For joiners' work a loss of one-third is necessary. Joiners' work is much improved by a second seasoning, and the framing is therefore, whenever possible, left in an unfinished state for some months before being finally completed.

Diseases.—The quality of timber is often injuriously affected by accidents to the growing tree. These may be caused by lightning, high winds, etc. The splits thus produced in the wood are known as *heart-shakes* when in the centre of the tree, *star-shakes* when the splits are radial, and *cup-shakes* when they follow the direction of the annual rings. Living trees are also sometimes injured by the attacks of parasitic plants, insects, etc. Timber itself is liable to the attacks of fungi, which cause it to rot.

Wet rot is a disease of the growing tree, and also of timber which is allowed to become saturated with water. It results in a decomposition of the tissues of the wood.

Dry rot attacks unseasoned timber to which there is not a free access of air. The disease is caused by a fungus which reduces the fibres of the wood to powder. Disease in a log can be detected by the fact that the wood will not convey sound well. Wood may be preserved from rot by thorough seasoning and good ventilation, and also to a large extent by painting, charring, creosoting, etc., after seasoning.

Varieties of Timber.—Most of the timber used in this country is imported. As has been already mentioned, timber is classed as soft wood and hard wood. The soft woods in most general use are red deal, yellow pine, pitch pine, and white deal.

Red deal, *red or yellow fir*, and *northern pine*, are names given to the wood of the Scotch fir (*Pinus sylvestris*). This wood contains a large quantity of resin, and is particularly suitable for out-door work and most carpenters' work. It is

one of the strongest and most durable of soft woods. The best quality is obtained from Memel, Dantzic, Riga, and St. Petersburg.

Yellow pine is the wood of the American pine (*Pinus strobus*). It is very soft, easily worked, and is extensively used for internal joiners' work. It is imported from Canada.

Pitch pine also comes from North America. It is the wood of *Pinus rigida*. This wood contains much resin, and often has the grain very beautifully marked. Being heavy, and obtainable in long lengths, it is much used for beams and engineering work generally. It is also much used for the interior finishings of superior joiners'-work.

White deal or *spruce* is the wood of the spruce fir (*Picea excelsa*). It is obtained from Northern Europe and from North America. It is inferior to red deal, being more liable to shrink and warp. It contains hard, glassy knots, which prevent its being used for fine work. It is chiefly employed for scaffolding, and for the rougher constructional work such as floors, roofs, etc., in buildings.

Hard Woods.—Of the hard woods, oak is the most generally useful. Many varieties of oak exist, but none is superior to British oak. It is used for engineering work in situations where great strength and durability are necessary. In buildings it is used for sills of window frames, treads of stairs, for wedges, keys, and other fastenings, and for superior finishings.

Other varieties of hard wood used for building construction include mahogany, walnut, teak, birch, ash, sycamore, elm, etc.

Timber varies in weight from 30 to 50 lbs. per cubic foot when dry.

Summary

Quicklime is obtained by heating limestone. On adding water to quicklime it becomes *slaked lime*. *Fat* lime is almost pure; *poor* lime contains various impurities; *hydraulic* lime, owing to its consisting partly of clay, sets in water and in damp situations.

Cements are (1) natural; (2) artificial. They do not slake on the addition of water. *Roman* cement is a natural cement obtained by strongly heating the septarian nodules of the London Clay. It sets quickly, but never becomes very strong. *Portland* cement is prepared by strongly heating an *artificial* mixture of chalk or limestone and clay. It sets slowly, and eventually becomes very strong.

Concrete is a mixture of cement or lime with sand, broken stones, and water. It is used for the foundations, fire-proof floors, roofs, etc., of buildings.

Mortar is a pasty mixture of sand with either lime or cement. It is used both for bedding stones and bricks, and for plastering.

Bricks are obtained by moulding clay into rectangular blocks, which are afterwards burnt in kilns.

The commonest **building stones** are *sandstones*, *limestones*, and *granites*.

Sandstones consist of grains of quartz cemented together. The weathering properties depend upon the nature of the cementing material. The best sandstone is obtained from Craigleith.

Limestones are composed chiefly of carbonate of lime. They vary greatly in hardness and durability. Marble is a hard, altered kind of limestone.

Granite consists typically of quartz, felspar, and mica. It is chiefly used for heavy engineering work, and for decorative purposes.

Slates are used as roof-coverings, fire-grate mantels, larder-shelves, and also for dowels, etc. The finest slates are obtained from the Welsh quarries.

The difference between **cast iron**, **wrought iron**, and **steel** consists chiefly in the amount of carbon present.

Cast iron contains from 2 to 6 per cent. of carbon. It has a crystalline texture, cannot be welded, is brittle, and is hence much stronger in compression than in tension. It is used for columns, girders, etc.

Wrought iron contains only a trace of carbon. It is of fibrous texture, and is a little stronger in tension than in compression. It is used for girders, roof trusses, bolts, fastenings, etc.

Steel contains from 0.15 to 2 per cent. of carbon. It is prepared in the *cementation process* by adding carbon to wrought iron, or from pig-iron by the *Bessemer* and *Siemens-Martin* processes. Steel is about 20 per cent. stronger both in compression and tension than wrought iron, and is hence largely superseding the latter.

Timber should be cut down in the early winter, and should be at once *converted* so that on drying the wood may shrink without splitting. The wood is best dried, or seasoned, by exposure to the air. The quality of timber may be injuriously affected by accidents to the living tree causing "shakes," and by the attacks of fungi and other parasitic organisms. Wet and dry rot are among the diseases caused by fungi. Timber is classed as soft wood and hard wood. The chief soft-wood trees are the pines and firs, and are known to the builder as red deal, yellow pine, pitch pine, white deal, etc. Of the hard-wood trees, the oak is the chief. Others are mahogany, walnut, teak, elm, ash, birch, etc.

Questions on Materials

1. What is the difference between limestone and lime? What is each used for?

2. How do rich lime, poor lime, and stone lime differ from each other in composition and setting power? Which requires most sand for making mortar?

3. Explain the difference between Roman and Portland cement as regards weight, colour, strength, and rate of setting.

4. How is cement concrete prepared for foundations? What precautions should be observed during its deposition?

5. Draw up a brief specification governing the preparation of mortar for:—

(*a*) Internal plastering.
(*b*) Ordinary building purposes.

6. Give a general description of the manufacture of bricks. What is the effect of the presence of lumps of limestone in the clay used for brickmaking?

7. What is the difference in composition between sandstone and limestone?

8. What is meant by the "natural bed" of a sandstone or limestone? In what way has it to be attended to during building? Which sandstone is considered the best for building purposes?

9. What is the composition of granite? For what purposes is granite used?

10. State how you would judge of the quality of different specimens of roofing-slates.

11. What is the difference between steel, wrought iron, and cast iron? For what kind of stresses is each particularly suitable? Describe the difference in the appearances of a newly fractured surface of wrought iron and cast iron, when broken suddenly.

12. Describe briefly how steel is manufactured from pig-iron. How does it compare in strength with wrought iron?

13. Describe, giving illustrative sketches, the following terms as applied to timber:—annual rings; medullary rays; cup-shakes; star-shakes; heart-shakes.

14. At what time of the year is it best to cut down trees? What is meant by "converting," and what is its object?

15. Why should timber be seasoned? What effect has seasoning upon its weight and size? Describe a common method of seasoning.

16. Describe the difference between dry and wet rot. State how these diseases originate.

17. Mention the principal varieties, and describe the special uses of hard wood and soft wood respectively.

CHAPTER XV

FORCES AND THEIR MEASUREMENT

THE previous chapters have shown that one of the chief problems in Building Construction is to arrange among themselves the materials composing a building in such a manner that their weights and the other forces acting upon the materials shall be properly balanced, and the structure shall be stable. The general principles underlying the measurement of forces may with advantage now be briefly considered.

The Nature of Force.—Force may be defined as that which moves, or tends to move, a body at rest, or which changes, or tends to change, the direction, or rate of motion, of a body already moving. A familiar example of force is shown in gravitation, whereby an object has a tendency to fall to the ground. In order to support it, an upward force equal to the weight of the object must be exerted. The phrase "equal force" implies that forces can be measured. They are usually measured in this country in terms of the weights in lbs., cwts., etc. Any one who has seen a pulley, or lever, at work knows that the *direction* of application of a force can be changed. Evidently, then, forces can be represented *graphically*—by lines drawn to scale which can be arranged to exhibit at the same time both the magnitude and the direction of the forces. Thus, a weight of 10 lbs. can be represented by a vertical straight line of 10 units in length. If the unit of length be $\frac{1}{8}''$, the line will measure ten times $\frac{1}{8}'' = 1\frac{1}{4}''$; whereas, if the unit of force be represented by a length of $1''$, the graphic representation of the force will be a vertical straight line $10''$ long.

Resultant of two or more Forces.—(1) When two

or more forces together act at a point in the same direction and in the same straight line, the *resultant* force is equal to the sum of the *components*.

EXAMPLE 1.—(*a*) If two 10 lb. weights attached to a cord are hung upon the same nail, the resultant weight acting upon nail is $10 + 10 = 20$ lbs.

(*b*) If two *equal* forces together act at the same point in opposite directions, but in the same straight line, they neutralise each other, and the forces are said to be *in equilibrium*.

EXAMPLE 2.—A spring balance carries a weight of 6 lbs. The index finger of the balance shows that the spring exerts an upward force equal to the downward force—the weight and a state of equilibrium is obtained.

If two *unequal* forces together act at the same point in opposite directions, but in the same straight line, the resultant force is equal to the difference between the two forces, and is in the direction of the greater one.

It is evident, then, that the directions of the forces, and therefore the angles they make with one another, must be considered in determining the forces acting at any given point.

If a flexible string be attached to a weight, and then passed over a frictionless pulley, there will be the same tension in every part of the string, irrespective of any change of direction caused by using the pulley.

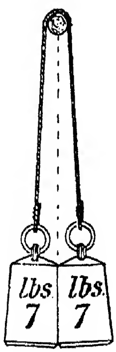


FIG. 624.—Two Forces acting in the same direction.

To illustrate these facts clearly, suppose that two 7 lb. weights, connected by a cord, hang over a smooth peg, as shown in Fig. 624. The total weight on the peg, neglecting the weight of the cord (which may thus be any length), is 14 lbs., the sum of the two weights.

Again, suppose three such pegs in a horizontal straight line, and the cord and weights to be passed over them, as shown in Fig. 625. Evidently the weight on the central peg is nothing. Now, suppose the outside pegs to be slightly lowered, as shown by the dotted lines in the figure, the central peg will now carry a small proportion of the weight, and the more the outside pegs are lowered, the more weight will be thrown on the central peg,

until, as shown in Fig. 624, it carries *all* the weight, *i.e.* 14 lbs. Therefore, the weight upon the central peg varies according to the *direction* of the forces acting on it, from nothing in Fig. 625 to 14 lbs. in Fig. 624.

The magnitude and direction of the resultant force acting upon the central peg, and upon each of the outside pegs, can be determined by the *parallelogram of forces.*

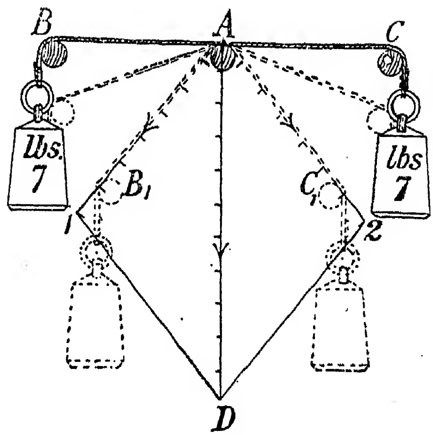


FIG. 625.—Arrangement of Weights with Cord passing over Pegs, to illustrate the Parallelogram of Forces.

The Parallelogram of Forces.—*If two forces acting at a point be represented in magnitude and direction by the adjacent sides of a parallelogram, the resultant of these two forces will be represented in magnitude and direction by that diagonal of the parallelogram which passes through this point.*

EXAMPLE 1.—The angle at A, when the cord passes over the pegs B_1AC_1, shown by the dotted lines in Fig. 625, is given. Determine by the parallelogram of forces the stress on the peg A, *i.e.* the single force acting through the point A, which shall be equal in effect to the forces AB_1, AC_1 acting together.

Produce AB_1 and AC_1, and mark off on each line 7 units, measuring from A. Then $A1$ and $A2$ represent in magnitude and direction the forces caused by the loads. Complete the parallelogram by drawing $1D$ parallel to $A2$ and $2D$ parallel to $A1$. The length of the diagonal AD, measured in the same units as the lines $A1$ and $A2$, represents the magnitude of the resultant force—*i.e.* the stress on the peg. The direction of the force will obviously be downwards. A force represented in magnitude and direction by DA would evidently counterbalance AD, and would therefore counterbalance $A1$ and $A2$ acting together. *Forces which balance each other are said to be in equilibrium.*

EXAMPLE 2.—Determine the magnitude and direction of the single force which will replace the two forces exerted by the cord and weight on the peg B_1 (Fig. 625).

Draw *ab*, 7 units long (Fig. 626), and parallel to the cord *A* 1 in Fig. 625. From *b* draw *bc* also 7 units long and parallel to the cord below the peg B_1. Complete the parallelogram by drawing *dc* and *ad* parallel to *ab* and *bc* respectively. Then, the diagonal *bd* gives the magnitude of the required force, and its direction is from *b* to *d*.

EXAMPLE 3.—Fig. 627 shows the application of the parallelogram of forces to determine the resultant force on the peg *B*.

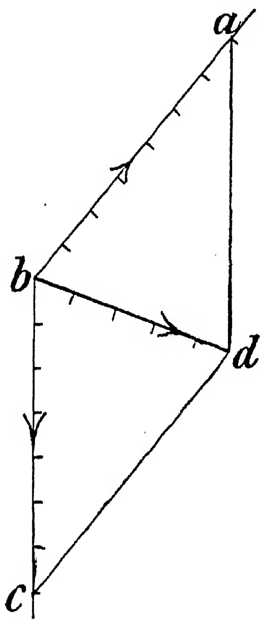


FIG. 626.—Diagram showing the Forces acting on the Peg B_1, Fig. 625.

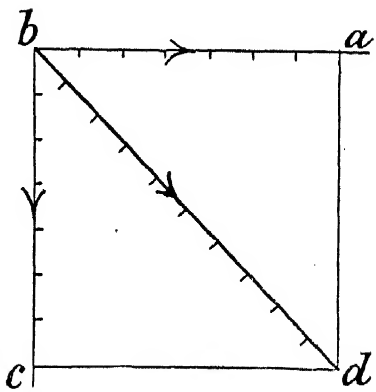


FIG. 627.—Diagram showing the Forces acting on the Peg *B*, Fig. 625.

In the above instances no allowance has been made for the weight of the cord nor for the friction on the pegs. It is assumed in each case that the forces are acting at the point of intersection of the straight lines produced.

EXAMPLE 4.—Two forces, of 9 and 6 lbs. respectively, act from a point and in directions which are at right angles to each other. Determine the magnitude and direction of the single force which can replace the two forces.

Let the line *AB* (Fig. 628) represent in magnitude a force of 9 lbs. acting at the point *A* in the direction indicated by the

arrow, and AC a force of 6 lbs. acting at right angles to AB. Complete the parallelogram $ACDB$. Then, the length of the diagonal AD represents the magnitude of the resultant force, and the direction in which the resultant acts will be *from* the point A, as shown by the arrow.

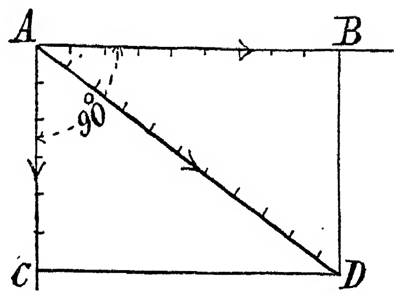


FIG. 628.

It must be clearly understood that a resultant is a force which can take the place of, and will produce the same effect as, two or more forces. To maintain equilibrium the resultant force must be counterbalanced by an *equal* force acting in the opposite direction. The force so acting is called the *equilibrant*.

Figs. 629 and 630 show the magnitude and direction of the resultant force when forces of 9 and 6 lbs. respectively act at angles of (*a*) 120° (*b*) 45°.

The simple apparatus shown in Fig. 631 clearly illustrates the principle of the parallelogram of forces. On a vertical board are fixed two small

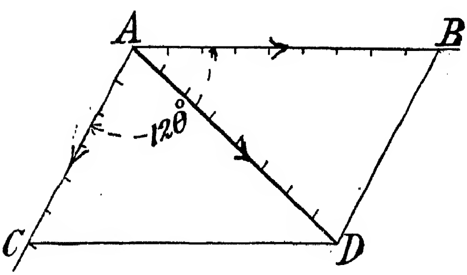


FIG. 629.

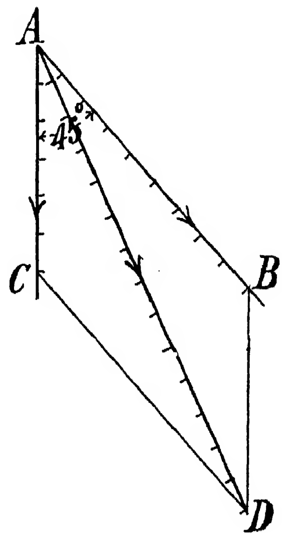


FIG. 630.

Examples of Parallelogram of Forces.

pulleys by means of screws, so that they revolve with as little friction as possible. By making a three-way string, passing it

over the two pulleys, and adding varying weights to each of the three ends of the string it can be clearly demonstrated how the three forces act. In Fig. 631 the weights are respectively 5, 6 and 4 lbs. By drawing the parallelogram *ABDC*, such that *AB* equals 5 units in length, and *AC* equals 4 units, the diagonal *DA* is found to measure 6 units—and to represent the magnitude of the middle weight. If other weights are attached to the ends of the strings different results will, of course, be obtained.

Triangle of Forces.—The triangle of forces is used to determine the magnitude and direction of any *three* forces

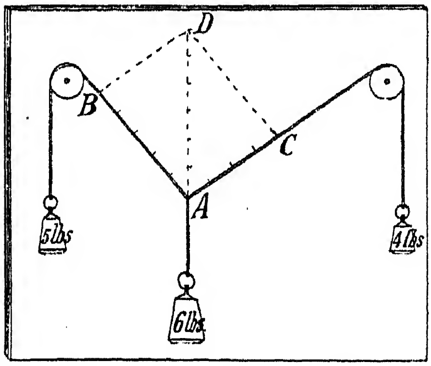


FIG. 631.—Apparatus to illustrate the Parallelogram of Forces.

which balance each other. The rule may be stated as follows: *If three forces acting at a point are in equilibrium they can be represented in magnitude and direction by the three sides of a triangle taken in order.*

EXAMPLE 1.—The forces acting upon *A* (Fig. 631) are in equilibrium. Since the length of the line $AB = 5$ units, and the line *BD* is parallel and equal in length to $AC = 4$ units, and the diagonal *DA* is in a line with the direction of the middle vertical weight and equal in length to 6 units; then the sides *AB*, *BD* and *DA* of the triangle *ABD* represent both in magnitude and direction the forces acting at the point *A*.

To save confusion it is usual, however, to draw a separate triangle to illustrate these forces. A somewhat different system of lettering also simplifies the consideration of these

forces. This is known as *Bow's notation.* In it the two letters denoting a force are placed one on each side of the line representing the force, that is, in the spaces between such lines. Thus in Fig. 632 the three forces acting at the point *O* are referred to as *AB*, *BC*, *CA* respectively.

EXAMPLE 2.—Given the magnitude (9 lbs.) and the direction (indicated by the arrow) of *AB*, and the angles which the directions of the 3 forces make with each other, it is required to find the magnitude and direction of *BC* and *CA* when the forces are in equilibrium.

Draw the line *ab* (Fig. 633) parallel to the direction of action of the force *AB*, 9 units long, and in the direction shown by

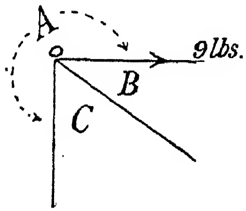


FIG. 632.—Three Forces acting at a Point.

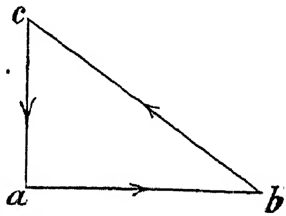


FIG. 633.—Triangle of Forces for Fig. 632.

the arrow. From *b* draw *bc* parallel to *BC* until it meets *ac* drawn parallel to *CA*. Then the triangle *abc* is the triangle of forces, and the direction of the forces *BC* and *CA* can be found by taking the sides of the triangle *in order*, viz. *a* to *b*, *b* to *c*, *c* to *a*; and these directions give also the directions of action of the forces represented by the lines parallel to *ab*, *bc*, and *ca* respectively. Thus, *AB* acts *from* the joint *O*; *BC* acts *towards O*; and *CA* acts *from O.*

The following examples further show the application of these principles to simple questions in Building Construction.

EXAMPLE 3.—A rope bears a tensile stress (pull) of 30 cwts. Find the magnitude of the stress in each of two other ropes which make an angle of 60° with each other, and which together balance the stress in the first rope, supposing the second and third ropes are equally stressed.

Fig. 634 shows the application of the triangle of forces to the solution of this question, the answer giving the stress in each

rope as 17.5 cwts. By going round the sides of the triangle in order, it will be seen that the forces in each of the three ropes act *from* the joint.

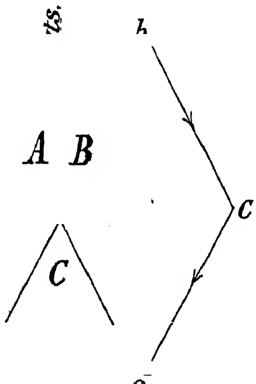


FIG. 634.

EXAMPLE 4.—A buckling-chain is used to raise heavy blocks of stone. What is the amount of stress in the links of the chain when raising a weight of one ton, if the buckling-chain is—

(*a*) Pulled tight as in Fig. 635.

(*b*) Placed loosely around the stone as in Fig. 636.

The correct solution of this question depends on (1) the weight of the stone; (2) the *angle* between the forces *AC* and *BC*.

The application of the triangle of forces in each case (Figs. 635 and 636) shows that the stresses *AC* and *BC* are more than twice as great when the chain is fixed as in Fig. 635 as they are with the arrangement in Fig. 636; or, the tighter the chain—

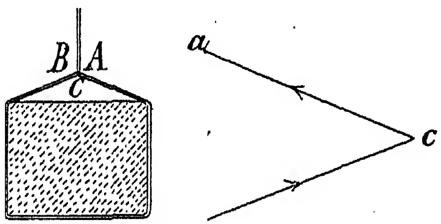


FIG. 635.—Stresses in a Buckling-chain when pulled tight.

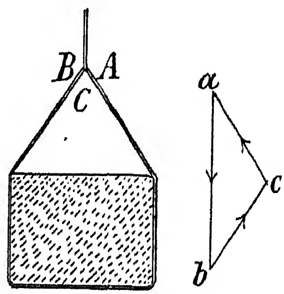


FIG. 636.—Stresses in a Buckling-chain when placed loosely round a Load.

i.e. the greater the angle between *BC* and *CA*—the greater is the stress on the links.

EXAMPLE 5.—A triangular bracket fixed against a wall, as shown in Fig. 637, has a weight of 5 cwts. suspended from the outer end *O*. What is the nature and amount of stress in each of the members *OA* and *OB*?

Fig. 638 is the triangle of forces used to determine these

stresses, and is drawn as follows: $1_1\ 2_1$ is drawn parallel to and represents the downward force (the weight of 5 cwts.) to scale. From 2_1 draw $2_1\ 3_1$ parallel to 2 3 in Fig. 637 until it meets $1_1\ 3_1$ drawn parallel to 1 3. Then the triangle $1_1\ 2_1\ 3_1$ represents the magnitude of these forces.

By going round the triangle in order as shown by the arrows we find that 2 3 acts towards the joint *O*, and is therefore a compression stress or *thrust*, and 3 1 acts from the joint, and therefore a tension stress or *pull*.

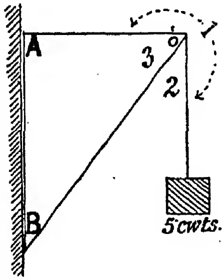


FIG. 637.—Line Diagram of Wall bracket.

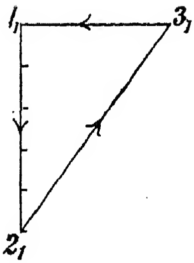
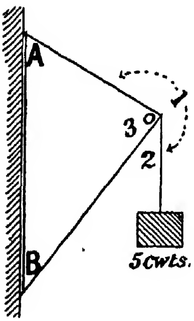


FIG. 638.—Stress Diagram for Fig. 637.

Fig. 639 shows a somewhat modified design of wall bracket, and Fig. 640 is the triangle of forces by which the stresses in the various members are ascertained.



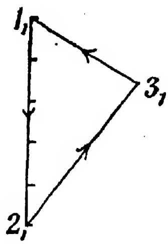


FIG. 639. FIG. 640.
Another form of Wall-bracket with Stress Diagram.

EXAMPLE 6.—What is the nature and amount of stress in each of the members *AB* and *AC* (Fig. 641) caused by the weight of 10 cwts. acting as shown?

This example may be taken as typifying a simple kind of sloping roof-truss, with the weight taking the place of the ridge piece.

Re-letter or figure the diagram according to Bow's notation. Draw the vertical line $2_1\ 3_1$, equal in magnitude and direction to the weight 2 3. Complete the triangle by drawing lines parallel to the members *AC* and *AB*, from points 2_1 and 3_1 respectively.

These lines represent the amount of stress along the members *AC* and *AB*. On taking the sides of the triangle in order as

shown by the arrows, it is seen that $2_1\,3_1$ acts downwards; $3_1\,1_1$ acts towards the joint A, as does also $1_1\,2_1$; therefore each member is subject to a compression stress (thrust).

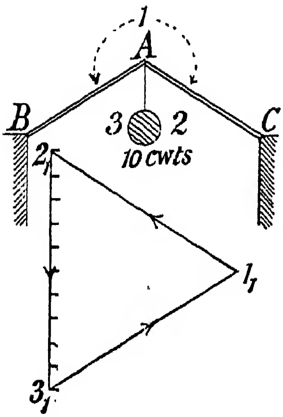


FIG. 641.

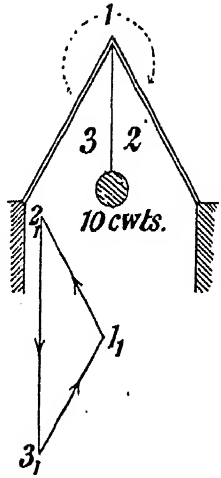


FIG. 642.

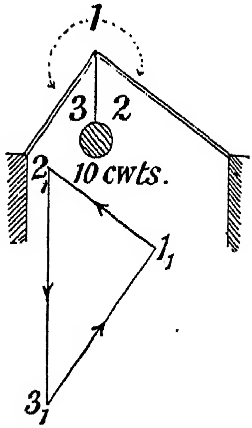


FIG. 643.

Examples typifying simple Roof-trusses.

Fig. 642 shows another example of this kind with a much smaller angle between the forces.

Fig. 643 illustrates a still further example, where the two sides are of unequal inclination.

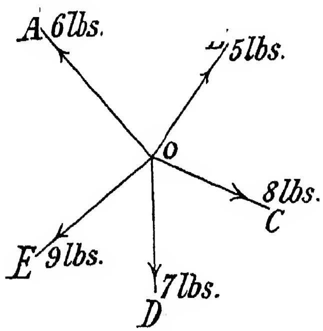


FIG. 644.—Five Forces acting at a Point.

Polygon of Forces.—The method of obtaining the resultant of any two forces acting at a point can be extended to three, four, or any number of forces.

EXAMPLE.—OA, OB, OC, OD, OE (Fig. 644) represent the magnitude and direction of five forces acting at the point O. Determine the magnitude and direction of the resultant force.

This problem can be solved either by an application of the parallelogram of forces or by direct construction.

(1) Determine by the parallelogram of forces the resultant $O1$, of forces OA and OB (Fig. 645). Similarly, determine the resultant $O2$ of forces $O1$ and OC. Again, $O3$ is the resultant of the forces $O2$ and OD; and, finally, $O4$ is the resultant of $O3$ and OE. Therefore, $O4$ is the resultant of *all* the original forces; or in other words, the single force equal in magnitude and direction to the force $O4$ will have the same effect at the point O as the five forces have when acting together. Since a force

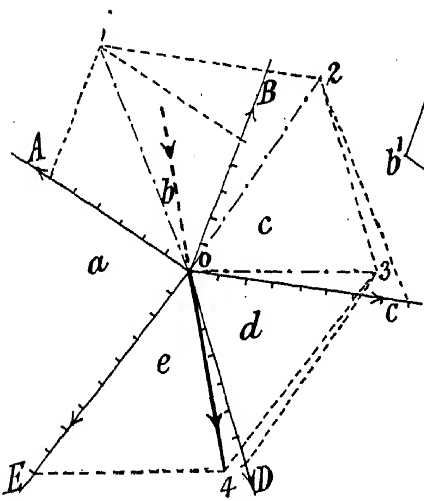


FIG. 645.

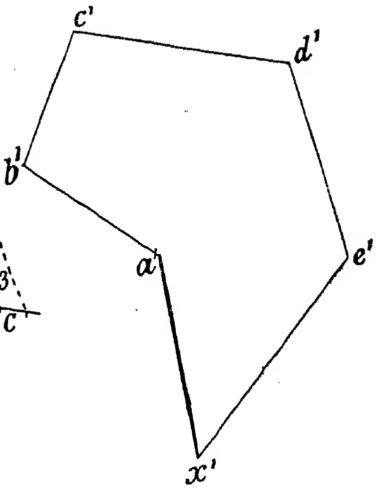


FIG. 646.

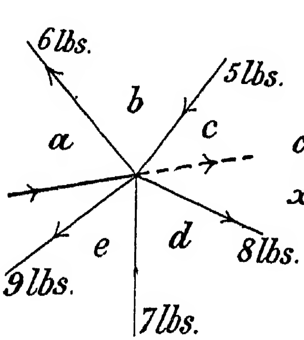
$4O$ will balance $O4$, a force represented in magnitude and direction by the line $4O$ will, together with the five given forces, produce equilibrium at the point O.

(2) The same result may be obtained more simply as follows: Re-letter the forces as shown in italics (Fig. 645), and then, as in Fig. 646, draw a straight line $a'\ b'$ equal in magnitude and parallel to ab in Fig. 645. From b' draw $b'c'$ equal and parallel to bc; continue the process, taking the forces in order. It will be found by drawing the closing line of the polygon, that is, by joining x' to a', that $x'a'$ gives the magnitude and the direction of the force required to produce equilibrium. Conversely $a'x'$ is the *resultant* of all the original forces. By

drawing the line $4O$ through point O (Fig. 645), and indexing it to scale, the required resultant—which corresponds with the one determined by the parallelogram of forces—is determined. Its direction is indicated by the arrow.

Fig. 648 is the polygon of forces when two of the forces *bc* and *de* act towards the joint (Fig. 647), the magnitude of all the forces being as in the previous example. In this case the equilibrant is determined, and is shown by the strong line in Figs. 647 and 648.

Figs. 646 and 648 should be carefully compared.



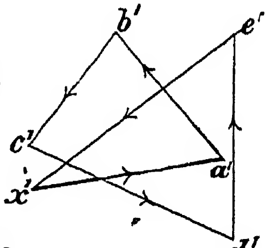


FIG. 648.

FIG. 647.

Examples showing the application of the Polygon of Forces.

The *polygon of forces* may be stated as follows: *If two or more forces act at a point, then, if starting at any point, a line be drawn to represent the magnitude and direction of the first force, and from the point thus obtained another line be similarly drawn to represent the second force, and so on until lines have been drawn representing each force, then the resultant of all these forces will be represented by a line drawn from the starting-point to the point finally reached.*

Polygons, parallelograms, or triangles, of forces, when used to determine either the resultant or the equilibrant of stresses acting at a point, are called *reciprocal diagrams*.

Parallel Forces.—In addition to forces acting in the ways already explained, it is necessary to consider a few examples of parallel forces. These must not be mistaken for those dealt

with by the parallelogram of forces, as they are entirely different.

In all the examples now to be considered the forces will act vertically. As these can be easily shown both graphically and arithmetically, and serve also to illustrate the principle of the lever, each example will be worked by both methods.

The simplest kind of lever is shown in Fig. 649, where a straight bar rests upon a triangular block c, called a *fulcrum*. The conditions in such a lever when in equilibrium are:—

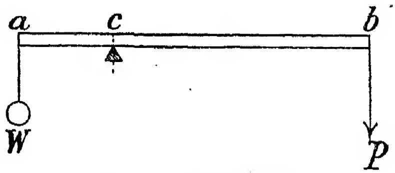


FIG. 649.—Simple Lever.

Weight at a *multiplied by the arm of* a (i.e. *the distance from* a *to* c) = *force at* b *multiplied by the arm of* b (i.e. *the distance from* b *to* c).

In considering these forces graphically the polygon of forces

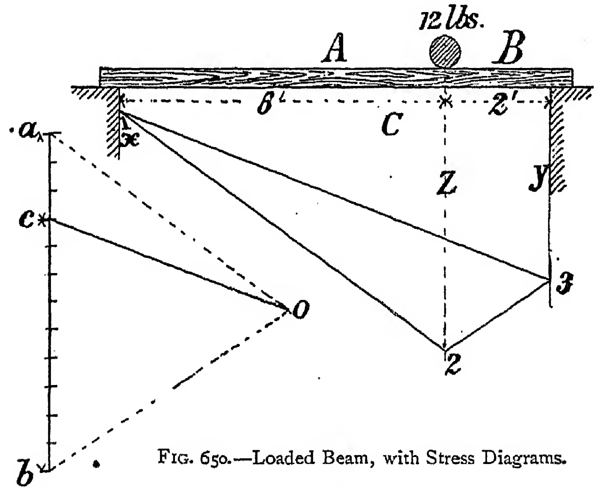


FIG. 650.—Loaded Beam, with Stress Diagrams.

becomes a vertical straight line. What is known as a *polar diagram* is required, the construction of which will be understood by an examination of Figs. 650 to 654.

EXAMPLE 1.—A beam rests upon supports placed 8′ apart.

A weight of 12 lbs is placed on the beam at a distance of 2 feet from the right-hand support. What amount of the weight is carried by each of the supports, the weight of the beam being neglected?

Fig. 650 shows the beam and supports with the load in position. The polar diagram is drawn as follows: Draw a vertical line, *ab*, representing the weight (12 lbs.) to a scale of $\frac{1}{8}''$ equals 1 lb. From any point *O*, which may be at any convenient distance from the line *ab*, draw the triangle *Oab*. Draw as in the figure a vertical line directly under the load, and one under each point of support, as *x*, *y*, *z*. Letter the load *AB*, and the space between the supports *C*. These letters can now be used to denote the reaction at each point of support—*i.e.* the upward force required to maintain equilibrium—which is equal and opposite to the pressure exerted on each support by the load. Anywhere, as from *x* draw, in the space *A*, a line 1 2, parallel to *AO*; from 2, in the space *B* draw 2 3, parallel to *Ob*. Join 1 3, and, through the pole *O*, draw *Oc* parallel to 3 1. Then *ac* (on the vertical line of loads *ab*) represents to scale the pressure on the left-hand support, and *cb* to the same scale represents the pressure on the right-hand support.

As the reaction at each end is equal in magnitude and opposite in direction to the pressure, *ac* gives the amount of the reaction *AC*, and *bc* gives *BC*; and the sum of the reactions—both acting upwards—is equal to the total weight (12 lbs.).

EXAMPLE 2.—A beam is loaded as shown in Fig. 651. Determine the reaction at each end, that is, the upward force required at each point of the support to maintain equilibrium.

Construct the vertical line of loads, representing to scale the sum of the weights as shown in the figure. Fix the pole *O*, and draw the dotted lines *Oa*, *Ob*, *Oc*, *Od*. Letter the loads and draw the dotted vertical lines directly under each load and under each support as shown. Anywhere, in the space *A*, draw a line 1 2 parallel to *aO*; from 2 draw 2 3, parallel to *bO*; from 3 draw 3 4, parallel to *cO*; and in the space *D*, from 4, draw 4 5, parallel to *dO*. Join 1 to 5. This diagram is called the *funicular polygon*. By drawing a line parallel to 5 1,—the closing line of this polygon—through pole *O*, and

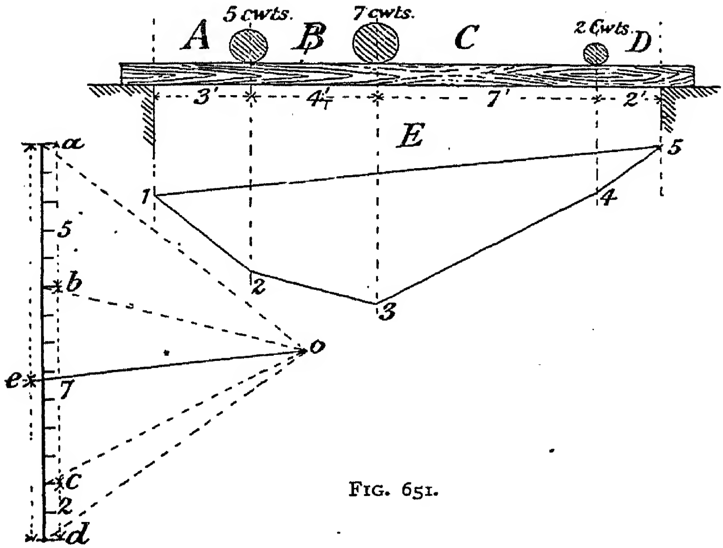


FIG. 651.

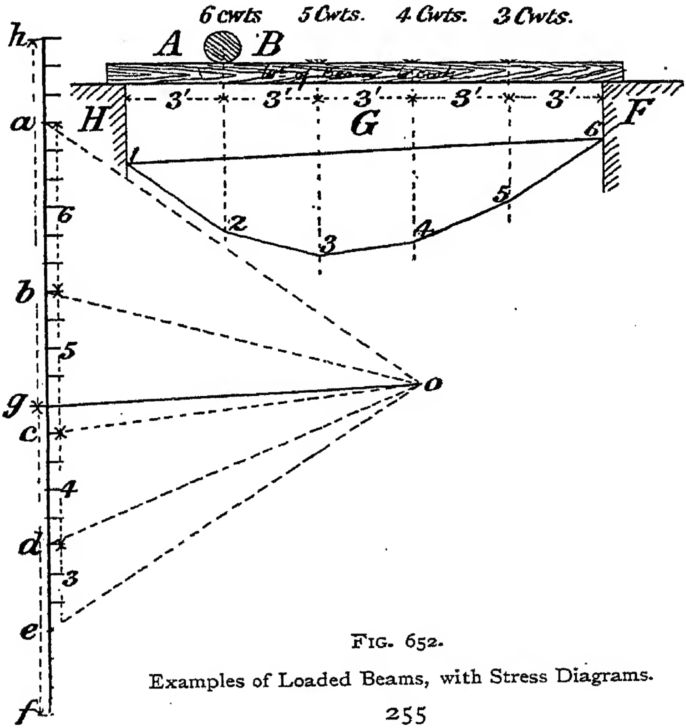


FIG. 652.

Examples of Loaded Beams, with Stress Diagrams.

meeting the vertical line of loads at *e*, it is found that *ea* equals the reaction *EA*, and *ed* equals the reaction *ED*; they are together equal to the sum of the weights on the beam.

EXAMPLE 3.—A beam weighing 6 cwts. is loaded as shown (Fig. 652). Determine the reaction at each end necessary to produce equilibrium.

The illustration shows the solution obtained as in the two previous examples, by the polar diagram and the funicular polygon respectively. The only difference between this and the last example is that the weight of the beam is considered. In drawing the line of loads, one-half the weight of the beam is added at each end.

EXAMPLE 4.—A horizontal bar 3′ long has a weight of 2 lbs. at one end and of 4 lbs. at the other end. Find the point at which the bar must be supported so that it will rest horizontally. (Neglect the weight of the bar.)

Fig. 653 shows the bar with the weights suspended. Letter the forces *AB* and *BC*. Draw the vertical line of loads 6 units long—equal to the sum of the weights. Complete the polar diagram by drawing *oa*, *ob*, and *oc*. To construct the funicular polygon, draw, in the space *B*, 1 2 parallel to *bO*. From 1 draw 1 3 parallel to *aO*; and from 2 draw 2 3 parallel to *Oc* until they meet in 3. Then the vertical line drawn through the point 3 will give the position of the fulcrum. If the distances from this point to the point of application of the weights be measured, it will be found that they are in inverse proportion to the magnitude of the weights, and that the weight on the right-hand side of the fulcrum, multiplied by the length of the arm of leverage, will be equal to the weight on the left-hand side, multiplied by the length of the arm of leverage on that side—the arms in this case being one and two feet respectively.

EXAMPLE 5.—Four weights of 2, 3, 6, 4 lbs. respectively, hang on a bar as shown in Fig. 654. Determine the point at which the bar must be supported to rest horizontally, the weight of the bar being neglected.

Draw the polar diagram and funicular polygon as shown in Fig. 654 and as explained in the previous examples. The point of support is obtained by drawing the lines 1 5, and 4 5, through points 1 and 4, and parallel to *Oa* and *eO* respectively.

Arithmetical Solutions.—The general principle used, in

solving the previous problems arithmetically, is as follows:—*The pressure on one end caused by any load* bears the same

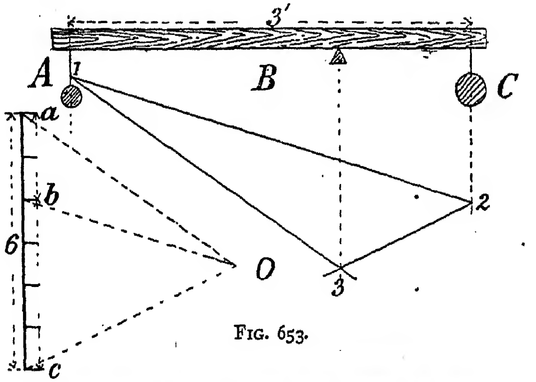


Fig. 653.

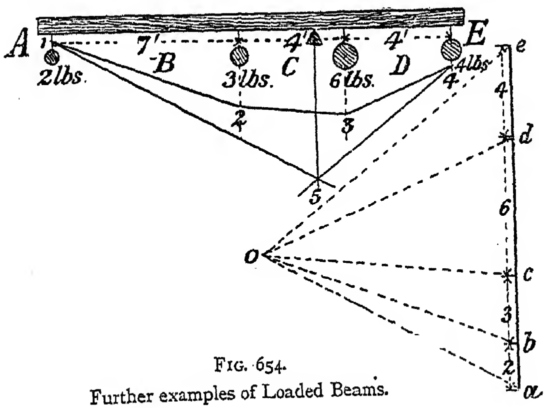


Fig. 654.
Further examples of Loaded Beams.

proportion to *that load* as does *the distance of that load from the other end* to *the length between the supports*, *i.e.*

Pressure on one end caused by any load : that load :: Distance of load from other end : Length between supports.

Apply this to Example 1 above—(Fig. 655).

$$\text{Pressure on } A : 12 \text{ lbs.} :: CB : AB$$

$$\text{Pressure on } A = \frac{12 \times CB}{AB} = \frac{12 \times 2}{8} = 3 \text{ lbs.}$$

Similarly $$\text{Pressure on } B = \frac{12 \times AC}{AB} = \frac{12 \times 6}{} = 9 \text{ lbs.}$$

It is clear that since the beam is in equilibrium there must be an upward reaction at each end equal to the pressure on that end.

EXAMPLE 2.—A beam is loaded as shown in Fig. 656. Determine the reaction at each end, that is, the upward force required at each point of support to maintain equilibrium.

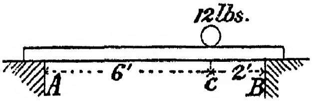


FIG. 655.

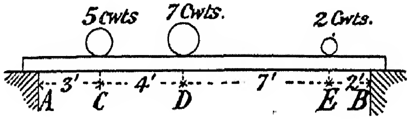


FIG. 656.

$$\text{Reaction at } A \text{ due to weight at } C : \text{W}^t. \text{ at } C :: CB : AB$$

$$\therefore \text{ Reaction at } A \text{ due to w}^t. \text{ at } C = \frac{\text{W}^t. \text{ at } C \times CB}{AB} = \frac{5 \times 13}{16}.$$

Similarly, $$\text{Reaction at } A \text{ due to w}^t. \text{ at } D = \frac{\text{W}^t. \text{ at } D \times DB}{AB} = \frac{7 \times 9}{16}.$$

Also $$\text{Reaction at } A \text{ due to w}^t. \text{ at } E = \frac{\text{W}^t. \text{ at } E \times EB}{AB} = \frac{2 \times 2}{16}.$$

The total reaction at A is equal to the *sum* of the partial reactions as shown above, or it may be obtained directly thus:—

$$\text{Total reaction at } A = \frac{(\text{W}^t. \text{ at } C \times CB) + (\text{W}^t. \text{ at } D \times DB) + (\text{W}^t. \text{ at } E \times EB)}{AB}$$

$$= \frac{(5 \times 13) + (7 \times 9) + (2 \times 2)}{16} = \frac{132}{16} = 8\tfrac{1}{4} \text{ cwts.}$$

Similarly

$$\text{Total reaction at } B = \frac{(\text{W}^t. \text{ at } C \times CA) + (\text{W . at } D \times DA) + (\text{W}^t. \text{ at } E \times EA)}{AB}$$

$$= \frac{(5 \times 3) + (7 \times 7) + (2 \times 14)}{16} = \frac{92}{16} = 5\tfrac{3}{4} \text{ cwts.}$$

EXAMPLE 3.—A beam weighing 6 cwts. is loaded as shown in Fig. 657. Determine the reaction at each end necessary to produce equilibrium.

When the weight of a uniform beam is to be considered, it may be taken as acting half-way between the supports, and must be treated as a separate weight, the problem being worked as in the previous example.

EXAMPLE 4.—A horizontal bar 3′ long has a weight of 2 lbs. at one end and of 4 lbs. at the other end. Find the point at which the bar must be supported so that it will rest horizontally. (Neglect the weight of the bar.)

The moment or turning effect of a force at any point is measured by multiplying the force by the distance between the point and the line of action of the force.

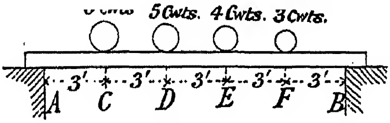


FIG. 657.

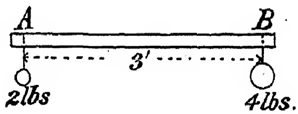


FIG. 658.

In Fig. 658 the moment of the force A (the weight of 2 lbs.) about the unknown point X (the fulcrum) equals $2 \times AX$. The moment of B about X equals $4 \times BX$, and if the beam is horizontal these moments are equal, *i.e.* $2AX = 4BX$.

The fulcrum at X supports the total weight, therefore the reaction at $X = 6$ lbs. acting upwards; and the moments of A and B, about A, are balanced by the moment of the reaction at X in the opposite direction.

Moment of A about $A = 2 \times 0$
,, ,, B ,, $A = 4 \times AB$
,, ,, reaction ,, $A = (2 + 4) \times AX$
$\therefore AX \times 6 = (2 \times 0) + (4 \times AB)$
$\therefore 6\,AX = 0 + (4 \times 3)$
$\therefore AX = \frac{12}{6} = 2$ feet.

EXAMPLE 5.—Four weights of 2, 3, 6, and 4 lbs. respectively hang on a bar as shown in Fig. 659. Determine the point at which the bar must be suspended to hang horizontally, the weight of the bar being neglected.

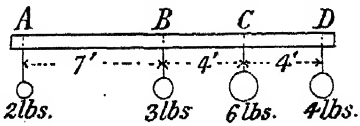


FIG. 659.

Let the required point of suspension be denoted by the letter X. To find the distance of X from the point A the moments about A must be equal.

$\therefore$ the downward moments about A

$$= (2 \times 0) + (3 \times 7) + (6 \times 11) + (4 \times 15)$$
$$= 0 + 21 + 66 + 60 = 147.$$

The upward moments about A

$$\begin{aligned} &= \text{Sum of all the weights } \times AX \\ &= (2+3+6+4) \times AX = 15\ AX \\ &\therefore 15\ AX = 147 \\ &AX = \tfrac{147}{15} = 9\tfrac{4}{5} \text{ feet.} \end{aligned}$$

King-post Roof Truss.—Figs. 660 to 665 show an application of the foregoing graphic methods to the determination of stresses in an ordinary king-post roof truss. Fig. 660 is a line diagram of the truss loaded in the usual way. It must be noticed that the lettering is arranged so that each member is indicated by a letter on each side. It is first necessary to determine the amount of weight carried by each point of support. This example is simplified by the symmetrical loading, as one-half the weight is carried by each point of support. When this is not the case the proportion of the weight carried by each support must be determined by a consideration of the parallelogram of forces, as in earlier examples.

It is usual when determining the stresses of such a truss to draw the stress diagram, shown in Fig. 665. This diagram is a combination of Figs. 661 to 664, which are only drawn as separate figures to assist in understanding the question more clearly.

Fig. 661 is the polygon of forces for the joint (1) at the foot of the principal rafter on the left. Four forces act at the point: AB downwards, BN the principal rafter, NG the tie beam, and the upward force, AG—the reaction at the point of support. Of these four forces the amounts of two, AB and AG, are known; it is required to determine the nature and amounts of the stress of BN and of NG when acting at the angles given.

Commence Fig. 661 by drawing ab equal to AB, and ag equal to AG, the upward force. As these two forces are in the same straight line, and in opposite directions, their resultant is the line bg. From b draw bn parallel to BN; and from g draw gn parallel to GN until bn and gn meet. Then bng is the polygon (a triangle in this case) of forces acting at the point, bn and ng representing the *amount* of stress in the principal rafter and tie-beam respectively.

The *direction* of the stress is found by taking the forces in

order; thus, *gb* acts upwards; *bn* acts towards the joint, therefore this member is in compression; *ng* acts from the joint, which indicates that the tie-beam is in tension.

At joint (2) four forces act, namely, *BC*, *BN*, *CM*, and *NM*. The two known forces are *BC* acting downwards and *BN* towards the joint. For the magnitude of the stress on *BN* has already been found, and its direction of action at joint (2) is the opposite to its direction at joint (1). Fig. 662 shows the application of the polygon of forces to this joint. In it, *bc* and *bn* are drawn equal and parallel to *BC* and *BN* respectively; and, by drawing *nm* parallel to *NM* and *cm* parallel to *CM*, the stress diagram is obtained. This shows that the stress in *CM*, the upper part of the principal rafter, is much less than in *BN*, the lower part. By tracing the polygon, it is found that *bc* acts towards the joint, *cm* towards the joint, (therefore *CM* is in compression), *mn* towards the joint (compression) and *nb* towards the joint (compression as in the previous figure).

At joint (3) there are four forces, *i.e.* *CM*, *CD*, *DL*, *ML*, acting as shown. Of these four forces the two *CM* and *CD* are known. Since the amount and nature of the stress in any member must be the same at any intermediate point between the joints, the stress in *CM* acting upon joint (3) must be as determined by the diagram for joint (2). Fig. 663 is the stress diagram; *cd* is drawn parallel and equal to *CD*; *cm* parallel and equal to *CM*; *ml* and *ld* are drawn parallel to *ML* and *LD* respectively until they meet. Taking these forces in order, *cd* is towards the joint, *DL* towards the joint (compression), *LM* is from the joint (tension), and *MC* towards the joint (compression).

The tension stress in *LM* is caused by the struts *MN* and *LH*, which transfer part of the loads at *BC* and *DE* respectively to the foot of the king-post. If no struts existed in this truss there would be no stress in *ML*.

Joint (4) has five forces acting, each one of which has already been determined, since the stress diagrams for one side of the truss are in this example applicable to each side. For example, the diagrams showing the stresses in the joints (1) and (2) are applicable to (6) and (5) respectively. An examination of Fig. 664 will show that *gn* is parallel and equal to *GN*; *nm* is

parallel and equal to NM; lm is parallel and equal to LM; and lh being drawn parallel to LH meets mn in n, whilst hg

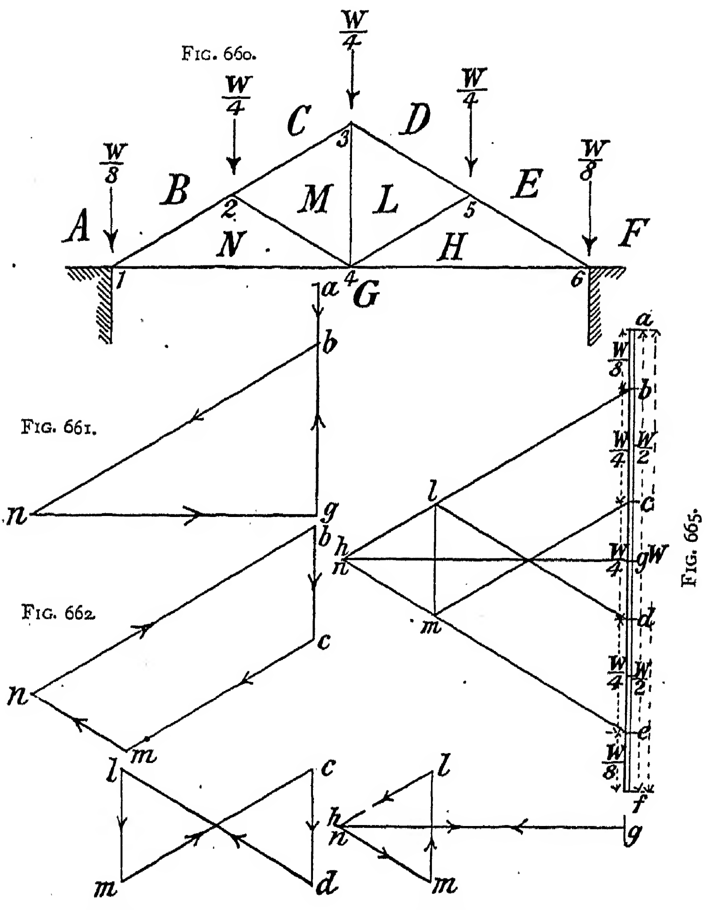


Fig. 663. Fig. 664.

Line Diagram of a King-post Roof Truss, with the Stress Diagrams.

is equal to ng. The diagram therefore shows the stress in each of the five members.

In Fig. 665, which is the complete stress diagram for the members of the truss, the lettering is identical with that in

each of the separate Figs. 661 to 664, and will be easily understood from them.

Questions on Forces

1. Represent graphically a weight of 10 lbs. to a scale of $\frac{1}{4}''$ to the lb.

2. Represent graphically to a scale of $\frac{1}{2}'' = 1$ lb. the resultant of two forces of 6 and 4 lbs. respectively acting at the same point :—
   (*a*) In the same straight line but in opposite directions.
   (*b*) In the same straight line and in the same direction.
   (*c*) At right angles to each other.
   (*d*) At an angle of 135 degrees with each other.
   (*e*) At an angle of 60 degrees with each other.

3. Two forces of 8 and 5 lbs. respectively act at a point in directions making an angle of 120 degrees. Represent graphically a third force which, acting at the same point, will maintain equilibrium.

4. A triangular bracket, the sides of which are 6′, 8′, and 10′ long respectively, is fixed with the shortest side horizontal. The bracket carries an equally distributed load of 10 cwts. placed on the horizontal member. Find the stress in the longest side (spur).

5. A hinged square platform at the door of a warehouse projects 5′ from the face of the wall when horizontal, the outer corners being supported by two chains having their upper ends fixed into the wall at a height of 8′ vertically above the ends of the platform. The platform is uniformly loaded with 2 tons. Find graphically the tension in each chain.

6. Three equal poles meet at a point 12′ high, their lower ends being at the angles of an equilateral triangle of 8′ side. Find graphically the stress in each pole when a load of 3 tons is suspended from the joined upper ends of the poles.

7. From a point draw six lines so that each makes an angle of 60 degrees with the next. Forces of 5, 6, 7, 8, 9, 10 lbs. respectively act from the point of intersection along the lines. Find graphically the magnitude and direction of the resultant force.

8. With the data of the last question find the resultant if two of the forces, viz. those of 6 lbs. and 9 lbs., act *towards* the point.

9. A beam rests on supports 10′ apart. A weight of 8 cwts. is placed 2′ 6″ from one support. Determine both graphically and arithmetically the reaction at each point of support. Neglect the weight of the beam.

10. A beam rests on supports 12′ apart. Loads of 2, 4, and 6 cwts. respectively are placed at 3′ distances. Determine the reaction required at each end to keep the beam in equilibrium. Neglect the weight of the beam.

11. A plank carried on the shoulders of two men weighs 6 lbs. pe linear foot and is 24′ long. One man supports the plank 6′ from on end and the other 2′ from the other end. What weight does eacl man carry?

12. A beam 9′ long carries loads of 2, 3, 4, and 5 lbs. respectivel at distances of 3′ apart. Find the point at which the beam must b supported to remain horizontal. Weight of beam 2 lbs. per linear foot

CHAPTER XVI

SITES, VENTILATION, AND DRAINAGE

Importance of Site.—Great care is required in the selection of the site, or position, of a building, and several factors must be considered in order to ensure the health of its inhabitants.

The aspect, or position, of the rooms with regard to the sunlight is the first point to be considered. In towns, where the general direction of the street is already fixed, there may not be much choice in this respect, but generally speaking, a street running north and south is to be preferred, as this secures a greater abundance of warm sunshine than an easterly and westerly direction. When free choice exists, the streets are best arranged in an oblique direction, that is, north-east and south-west, or north-west and south-east, with the living rooms arranged to have a south-eastern or southern aspect. Rooms facing the north or north-east are usually cold and bleak, but for larders and storage rooms this is no disadvantage. The same remark applies to rooms—some workshops, etc.—in which direct sunlight is undesirable.

Subsoil.—It is above all things necessary that a dwelling-house shall be dry, and the character of the soil is therefore a very important consideration. A sandy, gravelly, or chalky soil is pervious to water, and thence brings about a natural drainage of rain, etc., which is very valuable. Clay, on the other hand, is impervious, and retains the water which falls upon it to such an extent that a house built on such a site is always more or less damp and unhealthy.

"Made" soil, or filled-up ground, is liable to contain decaying animal or vegetable matter, which not only gives off offensive gases, but may at any time contaminate the water

supply and give rise to disease. In addition, such a soil is so loosely compacted that it cannot be depended upon for secure foundations. For these reasons filled-up ground ought always to be avoided.

Even with otherwise satisfactory subsoils, neighbouring disused wells, mines, old and forgotten drains, cess-pools, rock fissures, etc., may be present and prove a source of danger. It is always safest, therefore, to have a site completely covered with concrete, extending from four to six feet beyond the building, and in cases where a made soil must be built upon this is absolutely necessary.

Height.—In many respects a valley is not so healthy as a hill. Low-lying ground is generally damp and the air consequently moist and liable to fogs and mists. The general bleakness of a hill is to be preferred to the stagnation of low-lying ground, and even to the strong currents of air which constantly sweep along many valleys. When a dwelling-house is built upon the hillside, the cliff behind should be excavated for some distance back, and have a gradual slope outwards.

Local Conditions.—The presence of a few trees in the vicinity adds to the healthiness of a site, if they are not so close as to interfere with the light and the free circulation of air. Trees not only purify the air, but render the house more attractive.

A site near boggy or swampy ground, especially if the latter lies to the south or west of the house, is almost certainly unhealthy.

Subsoil Drainage.—The character of a moist subsoil is materially improved by a system of drainage, whereby the excess water is carried off by pipes (drains) instead of being allowed to accumulate.

Generally speaking, a house near the sea is warmer in winter and cooler in summer than one farther inland. The south and west coasts of this country are warmer than the north and east coasts.

Ventilation and Warming

Ventilation may be defined as a system of renewing the air of a room in such a manner that the injurious gases are

got rid of as fast as they are formed without giving rise to draughts. The injurious gases referred to are formed (*a*) by the breathing of the inhabitants, (*b*) by the combustion of fuel, coal-gas, candles, etc.

In all these cases a suffocating gas known as *carbon dioxide* is produced, and accompanying this are other gases, as well as small particles of animal matter, which rapidly putrefy and become offensive.

Composition of Pure Air.—Air is a mixture of various gases. Roughly speaking, it consists of four-fifths *nitrogen* and one-fifth *oxygen*, but there are in addition small quantities of *water vapour*, *carbon dioxide*, and other compounds. Of these the proportion of carbon dioxide is most directly affected by the breathing of animals and the burning of fuel, and the quantity of this gas present is the most trustworthy criterion of the purity or otherwise of the air. Pure country air contains about 3 parts in 10,000, but air containing 6 parts of carbon dioxide in 10,000 may be breathed without ill effects; a larger proportion is injurious.

An average man at rest gives off three-fifths of a cubic foot of carbon dioxide per hour, and it has been computed that in order that the proportion may not become injurious, he must be supplied with 3000 cubic feet of fresh air per hour. This means that in a room 10′ by 10′ by 10′ constantly inhabited by one man, the air must be completely changed three times an hour, *i.e.*, once every 20 minutes. The rate of change for a number of persons, or a room of different size may be easily calculated from this. For example, a room 20′ by 15′ by 10′ contains 3000 cubic feet. With nine persons in it, the air would need to be completely renewed nine times per hour. If the persons in the room are taking exercise, or doing any manual work whatever, or if any lights—excluding electric lights—or fires are burning in the room, much more carbon dioxide will be given off, and more fresh air must be admitted.

It is evident that a much greater supply of fresh air will be required in workshops where manual labour is carried on throughout the day than will be the case in schoolrooms, where the rooms are only inhabited for comparatively short periods of time, or even in bedrooms, where the inhabitants are at rest.

Authorities differ somewhat as to the cubic space which ought to be allowed to each inhabitant, but the following instances will give a general idea of what is considered the minimum allowance in certain cases.

Lodging-houses	300 cubic feet per head.
Poor Law—healthy persons . ..	300 ,, ,, ,, ,,
—sick	850 to 1200 ,, ,,
Army Hospital Wards . . .	1200 ,, ,, ,, ,,
London Board Schools . . .	130 ,, ,, ,, ,,
Board of Education—Elementary Schools	100 ,, ,, ,, ,,

A draught may be defined as a perceptible current of air in a room. It depends upon (*a*) the speed of the current, (*b*) the difference between the temperature of the current and that of the air of the room. Warm air may enter a room much more quickly than cold air without inconvenience. A velocity of $1\frac{1}{2}$ to 2 feet per second for cold air, and 6 feet per second for warm air does not as a rule cause a draught.

The General Principles of Ventilation.—As air containing an excess of carbon dioxide is warm in ordinary cases at the time of the liberation of the carbon dioxide (from fires or the breath), and as warm air is lighter than cold air, impure air usually tends to rise and escape from the room either by the chimney or through openings near the ceiling. Cold fresh air flows in to supply its place. Ventilation is effected, therefore, by arranging suitably-placed outlets for the impure air, and inlets for the supply of fresh air.

Ventilation without Special Devices.—An ordinary room supplied with a door, window, and chimney-flue contains the means of more or less effective ventilation without any additional mechanical appliances. The fire heats the air above it and in its immediate vicinity, and this air consequently becomes lighter, rises, and escapes up the chimney. Its place is taken by cooler, and therefore denser air, which enters between the window sashes, under the door, and at the various crevices which exist around windows and doors. That such a circulation of air really does take place is well known to any one seated between the fire and an open doorway, the draught caused being especially noticeable in cold weather. Whenever possible the incoming air should be deflected upwards.

All *windows* should be made to open; a most effective

inlet for fresh air, with a minimum of draught, is obtained by having a deep staff-bead fixed on the sill of the window frame of a sash-and-frame window, thus allowing the lower sash to be raised from 2 to 3 inches without leaving an opening between the sash and the sill. This arrangement allows fresh air to enter between the meeting-rails, as shown in Fig. 666.

In mills and other workshops, schools, etc., the upper sash of the window is often hinged on the bottom rail and made to open inwards (Fig. 533), being regulated by a quadrant and cord; or made to swing on pivots, as shown in Fig. 534.

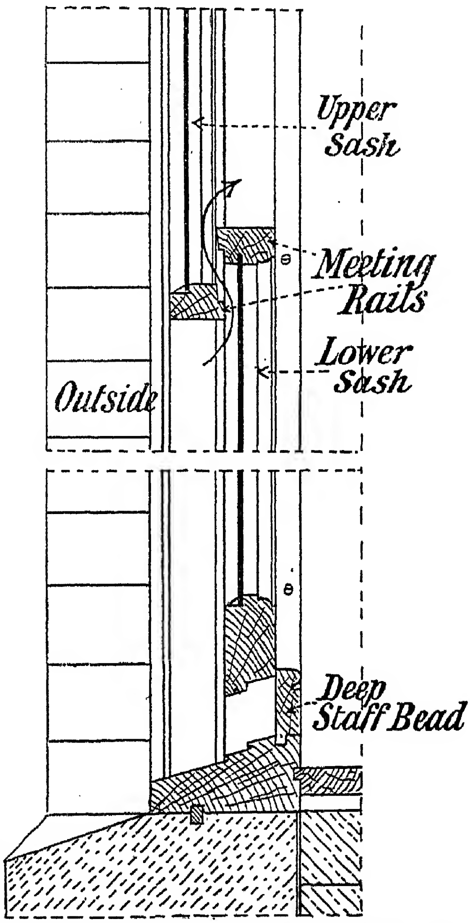


FIG. 666.—Vertical Section through the Meeting-rails and Sill of a Sash-and-Frame Window.

Specially arranged Openings for Ingress and Egress.—A few of the special arrangements which are in general use must be briefly described. Small rooms may be ventilated by having one of the window-panes fitted with *glass louvres*, *i.e.* strips of glass revolving on pivots and opening and closing like a Venetian blind. A somewhat similar device is a perforated disc of glass fitted on a perforated pane, and capable of rotation, so as to bring the openings together at will.

Sherringham's valve is one of the simplest examples of a wall ventilator; it consists of a metal box fixed in the wall at a height of from 6 to 8 feet above the floor, and opening to the outside by a grating. On the room side it is provided with a flap, which is so hinged that it can be opened or closed by means of a weight, cord, and pulleys. When open it allows the air to enter the room, and at the same time deflects it upwards.

Tobin's tube is a small vertical rectangular tube or trunk placed inside the room, against the wall, and opening at the lower end, which is two or three feet above the floor level, to the outer air. At the upper end, which is about 6 feet above the floor level, and which opens into the room, it is provided with a lid or "damper" for regulating the supply of air, and for closing when not in use. One advantage claimed for this tube is that, during the passage through it, the air is warmed by the heat of the room. Boyle's wall ventilators are similar in principle to Sherringham's valves and Tobin's tubes, but often contain in addition a canvas air-filter, which arrests dust.

A good arrangement is to have specially constructed ventilating flues built between the smoke flues. These prove very effective outlets, as the air in the flues is warm and at a lower pressure than that in the room, and hence causes a flow of air in this direction. The openings into the flues are placed near the top of the room, and are usually provided with ornamental gratings, and silk or mica flap-doors to prevent a back-draught. When the construction of the room will allow, as in schools, churches, theatres, and many public buildings, ventilators are fixed in the roofs. There is an almost innumerable number of designs of roof-ventilators, and as a rule they act very well. Even the efficiency of these, however, is improved by the presence of a gas-burner immediately beneath them.

In large public buildings some system of *mechanical ventilation* is almost indispensable. Many different methods are in vogue, and in most cases they serve at the same time for ventilation and heating. The general principle is as follows: cold air is drawn into specially arranged chambers, and sometimes passed through moist "brattice cloths" to remove the dust. In cold weather the air is then *heated* by passing over hot water- or steam-pipes, and is afterwards driven by means of fans along air ducts into the rooms.

Other means of heating rooms are by hot water or by steam. In each case a system of iron pipes is arranged so that a constant circulation of the hot water or steam takes place. Coils of pipes called *radiators* are fixed in suitable positions near windows and doorways in halls, corridors, etc., and aid in maintaining an equable temperature in the building. The detailed consideration of heating by hot water or steam is, however, beyond the scope of this book.

In ordinary dwelling-houses the open fire or the stove meets all normal requirements for heating purposes.

DRAINAGE

Necessity for Drainage.—That a building and its surroundings may be healthy, it is necessary to provide channels whereby the waste water and sewage from the scullery sink, the lavatory, w.c., etc., and the rain and surface water can be conveyed away from the building, either into the *sewers* that are found in all populous districts, or—where these do not exist—into specially constructed *cesspools*, for future distribution on the land. As the sewage is not only dangerous in itself to health, but readily decomposes and produces very offensively-smelling gases, great care is required in the construction of the channels or, as they are named, *drains*. Too much attention cannot be paid to a matter so vitally affecting the health of the people, yet experience shows that the arrangement and construction of drains do not always receive the consideration they deserve.

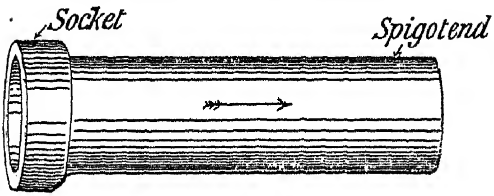
The Essentials of a good Drainage Scheme.—Although the arrangement of the drains is greatly influenced by the style and character of the building, the following may be considered most important essentials of a good drainage scheme. All drains should—

(1) be so laid that they be self-cleansing;
(2) have a uniform inclination downwards towards the sewer;
(3) be in straight lengths, with either a man-hole, inspection-chamber, or lamp-hole at any change of direction;
(4) have all the joints perfectly made, to prevent leakage;
(5) be trapped, to prevent any sewer-gas from getting into the building;

(6) be properly ventilated to prevent an accumulation of sewer-gas in them;

(7) be laid at such a depth below the ground that they shall not be damaged by any traffic over them.

Drain-pipes and Laying.—With the exception of heavy cast-iron pipes, which are considered too expensive for use in



667.—Sketch of a Socketed Earthenware Drain-pipe.

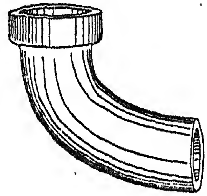


FIG. 668.—Bend.

ordinary circumstances, socketed stoneware, or earthenware, circular pipes are generally used for drains. These are manufactured in all sizes from three inches (3″) to two feet six inches (2′ 6″) internal diameter. Owing to a process of glazing which they receive by throwing salt into the kiln during the burning, they possess a surface which is both impervious and smooth, and thus offers as little resistance as possible to the

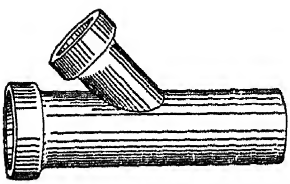


FIG. 669.

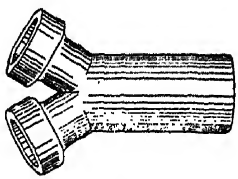


FIG. 670.

Junctions.

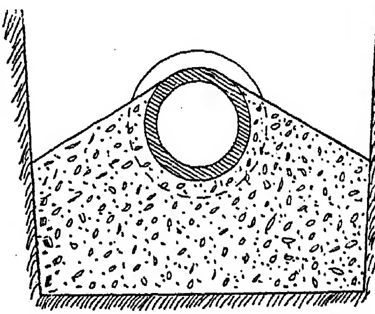
flow of the sewage. The pipes are usually made in two-feet (2′) lengths, and a socket on one end receives the "spigot" end of the next pipe (Fig. 667), and makes it possible to form a joint.

Wherever it is necessary to enlarge or diminish the size of a drain, *diminishing pipes*, that is, pipes tapering in their length, should be used. When the direction of the drain changes, *bends* (Fig. 668) of the required radius, and *junctions* (Figs. 669 and 670) are used. The use of these ought, how-

ever, to be in all cases strictly confined to drains for rain and surface water, since sewage containing solid matter tends to accumulate at the angle and block up the drain. When one drain joins another it should make an acute angle with the direction of the flow, as shown at *a* in Fig. 681.

It is important that in a system of drainage the pipes, although large enough to carry off the affluent, shall not be so large that the flow is sluggish; or any solid matter flowing through will be liable to collect. A four-inch (4″) pipe is generally considered large enough for branch drains, and a six-inch (6″) for main drains. It is evident that a four-inch pipe half full will be more likely to be self-cleansing than a six-inch with the same quantity of liquid flowing through it. The amount of *fall* required is influenced by the size of the pipe; it is usually taken as 1 in 40 for 4″ pipes (internal diameter), 1 in 60 for 6″ pipes, etc. These falls give a flow of about 3′ per second. With a greater fall than this any suspended matter is liable to be left behind the liquid, with a possibility of accumulations unless the drains are frequently flushed.

The nature of the ground through which a drain passes influences the method of laying the pipes composing it. All drains should be laid with a uniform inclination downwards to the sewer. In soft, loose ground the danger is that any drain passing through it will be liable to settlement and thus become blocked. To prevent this, all drains passing through such ground should be laid on a bed of concrete at least 6 inches in thickness, as shown in cross-section in Fig. 671. If the earth is good this concrete is often omitted. When such is the case the pipes, being often only supported by their sockets, are liable to fracture unless care is taken, when filling the trench, to ram the earth carefully around them. It



. 671.—Section through a Trench, showing the Drain-pipe resting on Concrete.

is at all times much better if concrete is deposited around the pipes, as shown in Fig. 672, before any filling of the trench takes place. Although drains should, as far as possible, be arranged so that they do not pass under, or through, any building, this cannot always be avoided: for example, in the drainage of a cellar, or where a long terrace of houses has only one main drain or sewer, into which the branch-drains from both the front and the back of the houses have to be connected. Drains passing under any building whatever should be always entirely enveloped in concrete, as shown in cross-section in Fig. 673.

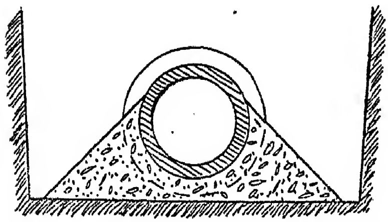


Fig. 672.—Section through a Trench, showing a Drain-pipe resting on Concrete.

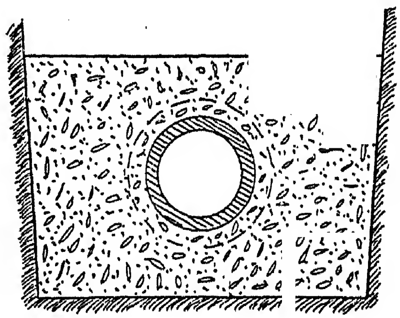


Fig. 673.—Section through a Trench, showing the Drain-pipe encased in Concrete.

Drain-pipe Joints.—The usual joint for connecting drain-pipes is shown in Fig. 674. The socket—which is always at the "head" end of the pipe—is from two to three inches (2″ to 3″) long, and a little larger in internal diameter than the outside of the spigot end of the pipe. The inner surface of the socket, and the outer surface of the spigot, end are left rough and unglazed to secure better adhesion of the cement. The two pipes are placed in position in the trench, carefully centred, tested for fall by means of a tapering straight-

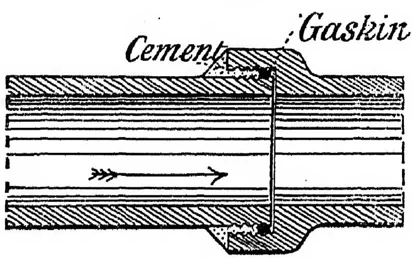


Fig. 674.—Usual form of Drain-pipe Joint.

edge and spirit-level, and then hempen rope (gaskin) soaked in liquid cement is wound round the spigot end of the pipe and carefully pressed into the socket. This tends to adjust the pipes and prevent any projections forming inside. The remaining space in the joint between the spigot and socket is now filled with a mixture of one part of Portland cement and one part of clean sharp sand, made into a paste with water, the outside of the joint being finished with a sloping surface (as shown in the figure). As the use of the gaskin adds to the trouble of making the joints, it is often omitted, and the joint entirely made with cement and sand. Defective results may arise from such a course, either from the pipes getting out of the straight line and forming lips or projections inside the drain, or from the liquid cement finding its way through the inside joints and forming a ridge which interferes with the flow. Whatever form of joint is used, the inside of the pipe should be examined after each joint is made, and any protuberance cleared away. This may be done by using a circular disc of wood with a rubber edge and called a "badger," or the joint may be wiped round with a cloth.

FIG. 676.

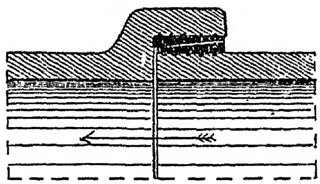


FIG. 675.

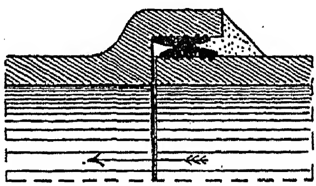
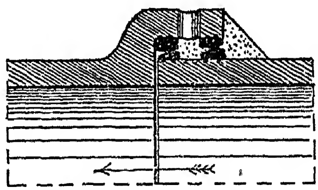


FIG. 677.



Various forms of Drain-pipe Joint.

Many patented forms of joint are in use; some of these are made by having the outside of the spigot end and the inside of the socket coated with a preparation of bitumen, either with a slightly curved surface (Fig. 675) or of conical shape (Fig. 676). Such joints are self-centring, and are completed by wiping the bituminous surface with a greased cloth and then simply forcing the spigot end of one pipe into the

socketed end of the other. The joint is made more secure by afterwards pointing round it with cement, as in Fig. 675. Fig. 677 shows a joint where a space left between the two layers of bitumen is filled with liquid cement, a hole being left in the socket for the purpose.

Traps.—The object of trapping a drain is to prevent the

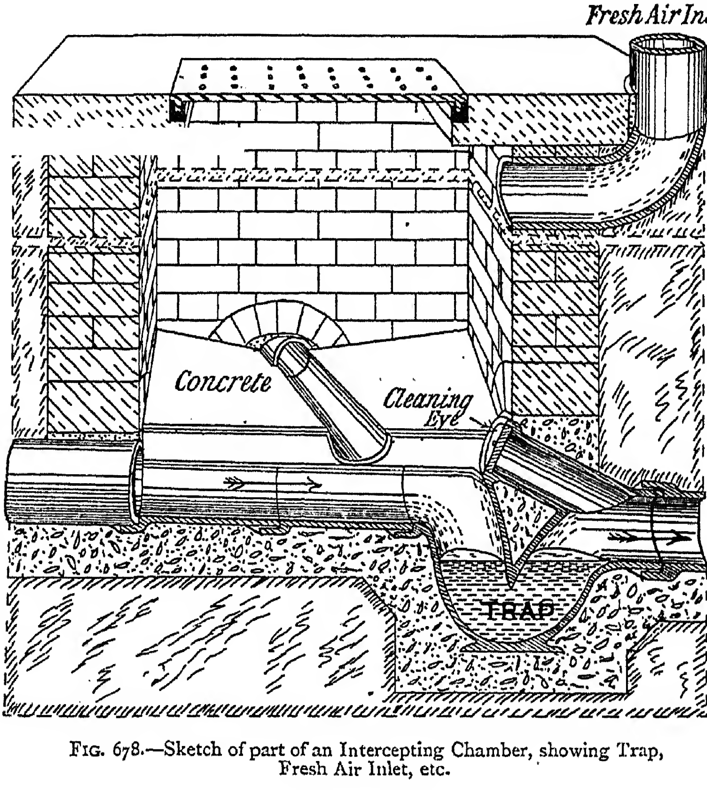


FIG. 678.—Sketch of part of an Intercepting Chamber, showing Trap, Fresh Air Inlet, etc.

passage of sewer-gas into the building. This is done by fixing specially shaped curved pipes, which, while allowing the sewage to pass through them, retain a quantity of water, and thus provide a water-seal. Such a sealed pipe is called a *trap*. Traps may fail to be effective through (1) evaporation; (2) syphonage; (3) pressure of sewer-gas forcing the seals.

Positions of Traps.—The two positions in which traps

are especially necessary are (1) as near as possible to the sewer, to prevent the escape of gas from the sewer into the drain, and (2) wherever any pipe from the building enters the drain, to prevent the escape into the building of any gas which may already be present in the drain.

Forms of Traps.—Many different forms of traps, with distinctive names, according to their positions in the drain, are in general use. Fig. 678 shows an ordinary *intercepting trap* in position between the intercepting chamber and the sewer. It is provided with an inspection- or cleaning-eye, to facilitate cleaning or the location of any obstruction. The cleaning-eye is provided with a sealed cover, which is only removed when necessary. Without such a sealed cover the trap would be ineffective. A water-seal of two or three inches (2″ to 3″) is provided, and, in order to render it self-cleansing, it is best to have the inflow on a higher level, by three to four inches (3″ to 4″), than the outlet.

A Gulley (Fig. 679) is a trap used at the inlet to a drain, where the rain-water pipe as well as the waste from the scullery-sink empties itself. It also provides an open grid for the reception of surface water, etc.

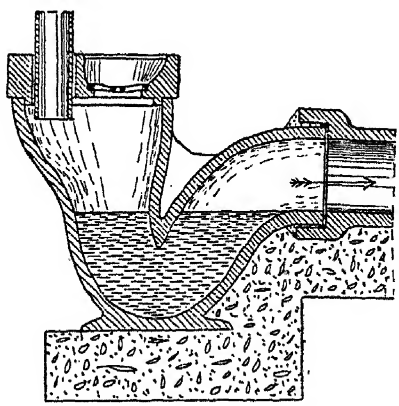


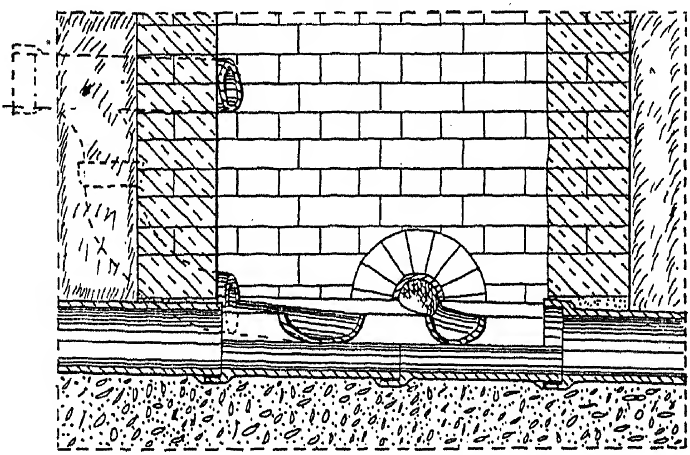
FIG. 679.—Section through a Gulley.

Inspection Chambers. — Whenever a change takes place in the direction of a drain, or where a drain is connected to a sewer, it is advisable to have a rectangular chamber (Figs. 680 and 681) built so that any blockage, leakage, or other defect can be located without the necessity of pulling up all the drains. This chamber should have a concrete foundation, and be constructed with the best kind of either glazed or blue bricks laid in cement mortar. The size will, of necessity, be somewhat influenced by the depth of the drain below the ground level, and by the number of branch drains entering it. It should be

large enough to allow a man to enter and examine the drains, and to manipulate easily any cleaning-rods if obstruction requires. If the chamber is deep, climbing-irons built into the wall will be required to facilitate entry.

The bottom of such a chamber may have specially prepared

FIG. 680.



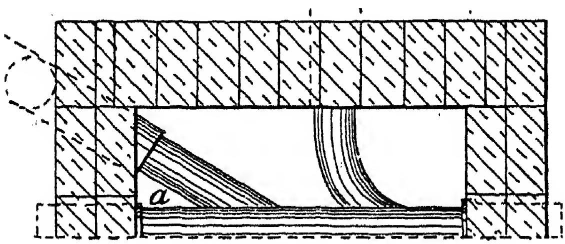


FIG. 681.

Longitudinal Section, and part Plan of an Inspection Chamber.

white glazed stoneware blocks, or may have U-shaped pipes of glazed stoneware—or earthenware—with branches for each inlet, all imbedded in cement; or it may be formed entirely of cement and sand, with the surfaces sloping, and there may be no ledge to act as a collecting-shelf for sewage. If a number of branch-drains enter into one chamber at different levels.

they should not be allowed to discharge in a cascade, but should be directed by bends and vertical pipes into the proper channel at the bottom of the chamber. The covers used for these chambers are generally of cast-iron, fitted into a frame, made air-tight, but still capable of being easily removed.

When very long straight lengths of drains exist it is sometimes an advantage to provide a lamp-hole to facilitate inspection. This consists of a vertical pipe of from six to twelve inches (6″ to 12″) internal diameter, provided with a sealed cover, fixed and connected to the drain by means of a right-angled junction in one of the drain-pipes. Such a lamp-hole sometimes takes the place of an inspection chamber at a change of the direction of the drain.

An intercepting-chamber (Fig. 678) is larger than an inspection chamber; it is placed as near the lower end of the drain as circumstances will allow, and contains an intercepting trap on the side nearest the sewer.

Ventilation of Drains.—All drains should be properly ventilated, to prevent an accumulation of sewer-gas. This can only be effectively done by having communication with the outer air at both ends of the drain. To ensure a sufficient current of fresh air, the cross-section of the ventilating pipe should be as large as that of the drain. The pipes should be of a material which is not liable to corrosion by sewer gas; lead is the best. All ventilating pipes fixed against a building should be arranged as far away from any window or other opening as possible, to guard against any sewer-gas the drains may contain entering the building. Generally speaking, the inlet is at the lower end of the drain, where a short vertical shaft provided with a mica-flap ventilator allows of the ingress of air; while the outlet fixed at the head of the drain, and acting as an exhaust, is obtained by carrying the ventilating pipe as high above the eaves as the building will allow, finishing at the top with either a cowl or a wire cage-like terminal. All intercepting chambers should be ventilated.

Tests for Drains.—Drains are tested to ascertain whether all the joints and connections are properly made or not. The test is made by blocking the lower end of the drain and then filling with water and thus putting it under pressure. During the testing, care should be taken that no air-blockage of the

drain takes place. No perceptible escape of water should occur. Other tests are: (*a*) the smoke test, made by igniting smoke-rockets in the lowest part and examining all the drains for smoke; (*b*) the smell test, in which small bottles containing a substance with a pungent odour are broken in the drain, and the drain examined for smell. In new drains the water-test is the one generally used.

In most drainage schemes of large extent, and in large towns where the sewage is specially treated, the rain or surface water is kept separate from the sewage; consequently two systems of drain-pipes exist. The rain water is at once sent into the river, while the sewage requires further treatment. In such cases it is necessary to have tanks, with automatic flushing arrangements, periodically to cleanse the sewage drains and to keep them clean. The surface water drains do not, as a rule, require an inspection chamber at each change of direction, the object being attained by using bends and Y-junctions. Care should, however, be taken to have the joints of these properly made with cement, and also to have them ventilated and trapped before they enter the sewer.

Summary

The best **aspect** for the living-rooms of a dwelling-house is a **south-easterly** one.

A *sandy* or *gravelly* soil is more likely to be dry than *clayey* ground.

All subsoils should be drained.

A house built upon a hill is more likely to be healthy than one on low-lying ground or in a valley.

Ventilation consists in renewing the air of a room without causing draughts. Dwelling-houses are usually ventilated by admitting fresh air through open windows; the impure air escaping either by the chimney flue or by a special flue built in the chimney stack.

Better ventilation is obtained by the use of mechanical appliances, amongst which are Sherringham's valves, Tobin's tubes, etc.

For large buildings, roof ventilators and fans are much used.

Drainage is necessary to carry off surface water and sewage. It is effected by means of pipes (called *drains* and *sewers*) laid in the ground. All drains should have water-tight joints, and should be laid with a uniform inclination downwards to the sewer, the fall being sufficient to render the drain self-cleansing.

All drains should be *trapped*, to prevent the escape of sewer gas

into adjoining buildings. They should be properly *ventilated* to prevent the accumulation of sewer gas.

An *inspection or intercepting* chamber or a *lamp-hole* should be placed at every change in the direction of a drain. Under certain conditions a *bend* or *junction-pipe* may be used instead.

Leakage and other defects in drains are tested for either with water under pressure, smoke, or a pungently-smelling gas.

QUESTIONS ON SITES, VENTILATION, AND DRAINAGE

1. What are the best aspects for the various rooms of a house?

2. What precautions should be adopted, when building a dwelling-house on land which is likely to be damp, to prevent the dampness from rising into the building?

3. What important considerations are necessary when building a house on a hill-side?

4. Briefly define ventilation. Why is it necessary, and what is its object? What are the results of defective ventilation?

5. Describe the simplest means of effective ventilation suitable for adoption in ordinary dwelling-houses.

6. What is the object of draining a building?

7. What are the most suitable materials to be used in a drainage scheme for a dwelling-house?

8. Make neat sketches of three different kinds of joints for earthenware drain-pipes, stating the nature of the materials used in making the joints. What is the amount of *fall* necessary when using 4″ pipes and 6″ pipes respectively?

9. What precautions should be adopted when a drain must be laid in loose ground?

10. What is the object of using a *trap*? Make a neat sketch of a disconnecting trap. What is meant by a water seal?

11. What is the chief object of an inspection chamber? What is the difference between an "inspection chamber" and an "intercepting chamber"?

12. Make detailed drawings of an inspection chamber when three 4″ drains, 3′ below the surface, meet and have to be directed into one main drain, as in Fig. 682. What should be the size of the main drain?

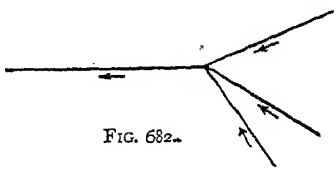


FIG. 682.

13. Briefly describe the object of ventilating drains.

14. What are the usual tests applied to ascertain whether the pipes and the joints of a system of drainage are efficient?

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SUPPLEMENTARY INDEX

COVERING CHAPTERS XV. AND XVI.